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START-STOP PRINTING TELEGRAPH SYSTEMS.

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DURING the last decade there have been extensive developments in the use of Type-Printing Telegraph Systems on inland circuits in this Country. Most of the circuits, carrying comparatively heavy traffic between zone centres, have been equipped with multiplex systems, and the working capacity of these is being increased by the substitution of automatic transmission for the direct hand transmission such as is still employed on a number of Baudot circuits. On the less heavily-worked circuits, over which the peak hour load does not exceed 100 to 120 average messages per hour in each direction, the tendency at the present day is to use Start-Stop Printing Telegraph Systems, and it is proposed in this and subsequent articles to describe such of these systems as are in extensive use. No attempt will be made to trace their historical development.

START-STOP PRINCIPLES.—All start-stop systems use a standard keyboard similar to that of a typewriter, and transmit signals direct to line through the agency of a mechanical distributor. The latter merely consists of a battery of cams, arranged to operate a number of transmitting contacts at certain regular intervals. At the receiving end, a single electromagnet controls, through another mechanical distributor, the action of the selecting and printing mechanism.

Both the sending and the receiving distributor are at rest, normally, but immediately a key is depressed at the sending end they are set in rotation. They are both stopped after completing one revolution. It is essential, of course, that the two distributors should rotate at the same speed, and this is ensured by governors and speed setting devices. If the speeds are set correctly and the governors function properly, very little phase displacement can occur between the distributors during each revolution; the slight changes of phase that may occur are insufficient to cause indifferent working and cannot accumulate because the distributors are brought into phase, automatically, each time they stop, which as explained, is on the completion of each revolution.

A five-unit code is used for the actual character combinations, but each is preceded by a " start " impulse, which is of the same length as each character unit, and followed by a " stop " impulse, which has a length of 1½ units. From a line transmission point of view each character, therefore, has a code length of 7½ units; hence start-stop systems have a slight advantage over Morse, in which the average length of a character is 8 units. The " start " and " stop " impulses are essential in order to ensure that the receiving distributor shall start and stop for each character signalled.

The application of the foregoing principles to the start-stop systems in use in this Country will now be described.

(i.) THE MORKRUM TELETYPE NO. 1A. — A

general view of this instrument is shown in Fig. **1**. The cover has been removed in Fig. **2** to show the mechanism. The Transmitting and Receiving units are mounted on one base and driven by a single series-wound motor of 1/40th H.P. Plugs and cords are fitted, which make connections with sockets mounted on the instrument tables, to facilitate the changing of the apparatus in the event of faults. The working speed is 40 words per minute, and printing is effected by bringing a paper tape into rolling contact with a rotating typewheel in a manner similar to that of the Baudot Receiver.

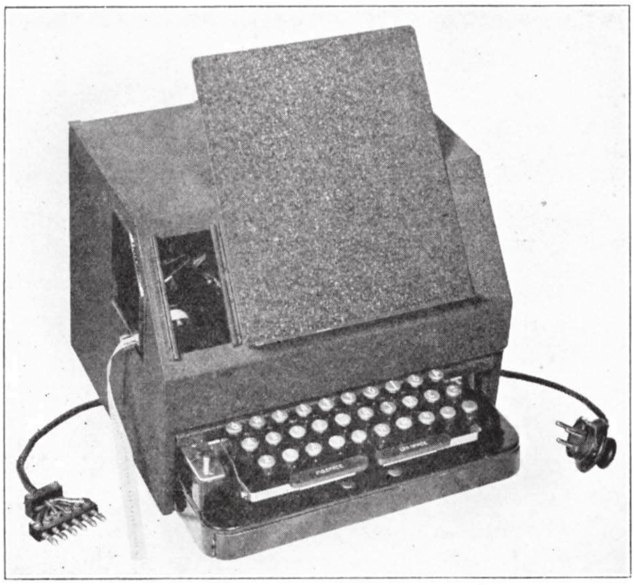


FIG. 1.—MORKRUM TELETYPE NO. 1A.

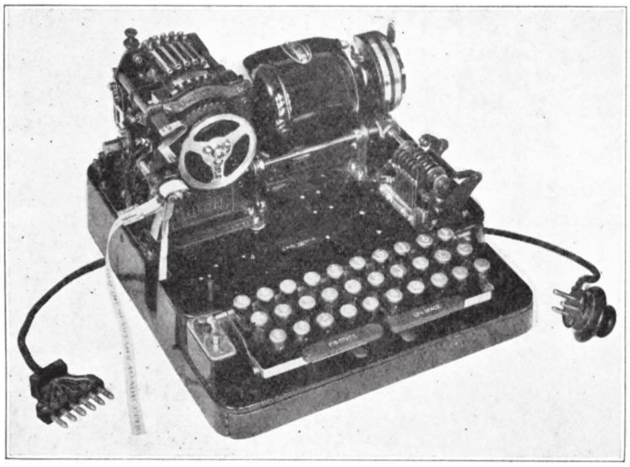


FIG. 2.—MORKRUM TELETYPE NO. 1A, WITH COVER OFF.

Morkrum Code

		1	2	3	4	5			1	2	3	4	5
A	:	●	●	○	○	○	Q	1	●	●	●	○	●
B	?	●	○	○	●	●	R	4	○	●	○	●	○
C	(	○	●	●	●	○	S	'	●	○	●	○	○
D	2	●	○	○	●	○	T	5	○	○	○	○	●
E	3	●	○	○	○	○	U	7	●	●	●	○	○
F	½	●	○	●	●	○	V	)	○	●	●	●	●
G	¾	○	●	○	●	●	W	2	●	●	○	○	●
H	⅝	○	○	●	○	●	X	£	●	○	●	●	●
I	8	○	●	●	○	○	Y	6	●	○	●	○	●
J	⅞	●	●	○	●	○	Z	·	●	○	○	○	●
K	⅜	●	●	●	●	○		+	○	●	○	○	○
L		○	●	○	○	●	/	/	●	●	●	●	●
M	!	○	○	●	●	●	–		○	○	○	●	○
N	-	○	○	●	●	○	FIGURES		●	●	○	●	●
O	9	○	○	○	●	●	LETTERS		○	○	●	○	○
P	0	○	●	●	○	●	BLANK		○	○	○	○	○

● Denotes "Marking" Units.

Each Character is prefaced by a start signal (spacing) & terminated by a stop signal (marking). The diagram below shows the signals sent out for one revolution of the Transmitter spindle for the letter "R"

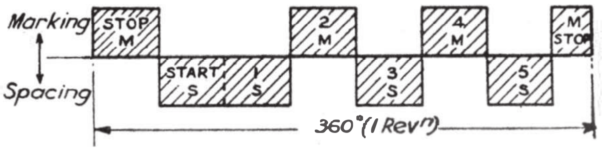


FIG. 3.

The five-unit code used is shown in Fig. **3**. It will be seen that the "start" impulse is a spacing unit, and the "stop" impulse a marking one of length 1½ units. Letter Shift and Figure Shift signals are employed, so that one particular combination of units may be made to represent either a letter or a secondary character

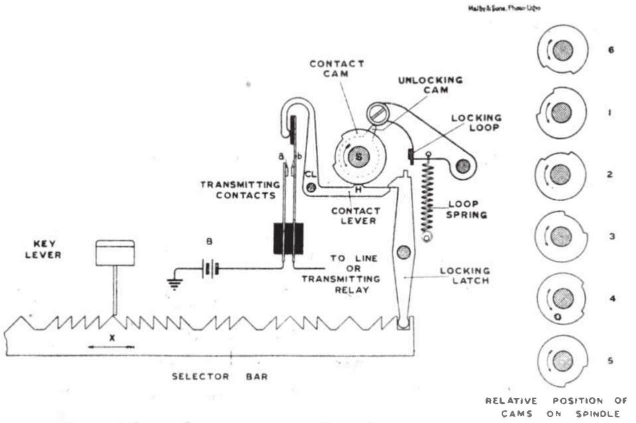


FIG. 4.

(such as figures, etc.) by preceding it with the " letter shift " or " figure shift " combination, respectively.

Transmitting Mechanism.—Referring to Figs. **4** and **5**, it will be seen that there are 5 selector bars directly underneath the key levers of the keyboard. The upper edges of these bars are notched in a definite manner to suit the code, and when a key is depressed it causes one or more of these bars to move either to the right or to the left according to the oblique side of the notch in each bar acted upon by the key lever. Thus in Fig. **4** the operation of the key lever shown would cause the selector bar to move to the left. The movement of any bar to the right represents a spacing unit of the code, and movement to the left a marking unit. For example, if key R be depressed, the code for which is 1, 3, and 5 spacing, and 2 and 4 marking, selector bars 1, 3, 5 will be moved to the right and bars 2, 4, to the left. Each Selector Bar acts on a Locking Latch, which, in conjunction with a Contact Lever, controls a Transmitting Contact. There are five such Contact Levers and Transmitting Contacts corresponding with the five Locking Latches. A sixth Contact Lever placed at the rear of the others controls a sixth set of Transmitting Contacts, which give the " start " and " stop " impulses.

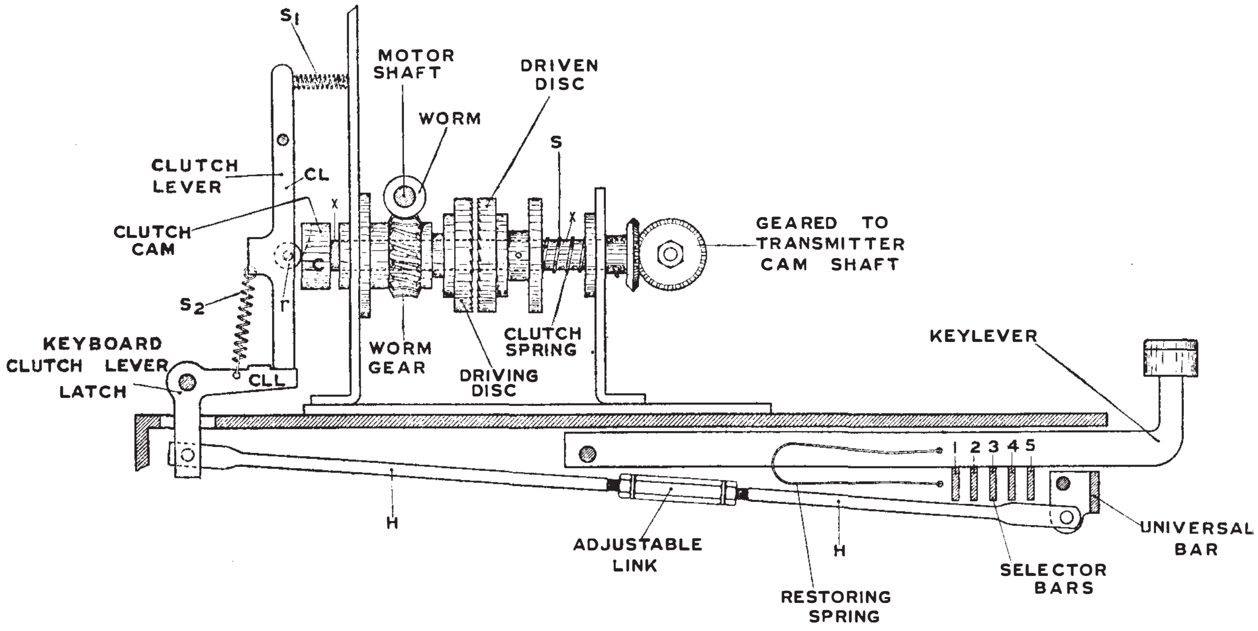


Fig. 5.

Simultaneously with the setting of the Selector-bars, which takes place when a key is depressed, a Universal bar is actuated bringing into operation a clutch mechanism and causing the Transmitter Cam spindle S to make one complete revolution. The six cams mounted on this spindle together with the associated contact levers and transmitting contacts, constitute the mechanical distributor of the Transmitter.

The contact spring *b* of each set of transmitting contacts acts on the end of its controlling contact lever and forces it to ride on the rim of its associated contact cam. The mechanical arrangements are such that when a selector bar is moved to the left, the upper end of its locking latch is positioned so as to be clear of the end of the associated contact lever and the projection H on the latter can rise into the notch in the cam on which it rides, thus allowing the contacts *a* and *b* to close and to send out an impulse. If, however, a selector bar is moved to the right, its locking latch will be moved to such a position as to prevent the contact lever from rising into the cam notch and the corresponding transmitting contacts will remain open.

All the six contact springs *a* are electrically connected to one pole of a battery B, while all the back contact springs *b* are connected to the line or to a transmitting relay, according as the circuit is to be worked single or double current. It is not possible for any two of the contacts to be closed simultaneously because the notches in the six cams are staggered as shown in Fig. 4.

When the cam spindle is at rest the sixth contact lever, which is not controlled by a locking latch, rises into the notch in cam 6 and closes the sixth set of transmitting contacts. Immediately the cams start to rotate, this lever is forced out of the notch and the contacts open. The circuit is not closed again until another contact lever rises into a cam notch. This break in the circuit, the duration of which is never less than the time of one unit, is the " start " impulse. After the five units representing the signal have been sent out by the cams, the sixth contact lever again closes its contact springs, sending out the " stop " impulse.

The locking latches are held in their set positions by the Locking Loop, which drops and engages with their upper ends when the cam spindle starts to rotate. This locks the selector bars and prevents the depression of another key until the character selected has been transmitted. The Unlocking Cam raises the Locking Loop and frees the latches just before the cam spindle completes its revolution.

Clutch Mechanism.—The clutch mechanism for driving the Transmitter Cam Spindle is shown in Fig. **5**.

The spindle XX, to which is fixed the Driven Disc, is normally at rest, but the Driving Disc which is mounted on a sleeve on XX rotates continuously. The Universal Bar is operated when a key lever is depressed and, in actuating the rod H, trips the Clutch Lever Latch CLL, thus unlocking the Clutch Lever CL and allowing the Clutch Spring S to move the spindle XX to the left. This brings about the engagement of the Clutch Discs setting in motion the Transmitter Cam Shaft. Fixed to the end of XX is a cam C, which bears against a roller *r* mounted on CL. Towards the end of the revolution of XX, spring S1 causes *r* to drop into a notch in the face of cam C, and CL is then re-engaged by CLL, which was restored to its original position by spring S2 immediately the key lever was released. As XX and the cam C continue to rotate, *r* rides out of the notch, but as CL is now locked by CLL the effect is to force C and therefore XX to the right and to uncouple the clutch discs. A jockey roller drops into a notch in the cam, fixed to XX, at the end of a revolution to ensure that the cam shaft will always come to rest in its proper position.

Receiving Mechanism.—This resembles in many respects that of the Baudot Receiver; only one electromagnet, however, is used for the reception of incoming signals. The principle of the selecting mechanism is shown in Fig. **6**. EM is the electromagnet, the armature of which is attracted when signalling is not taking place, because normally the sixth Transmitting Contacts at the Sending Station are closed and send out a marking current. On the receipt of the " start " signal, which precedes a character combination, this marking current ceases so that EM is de-energised and its armature is pulled upwards by the spring S3.

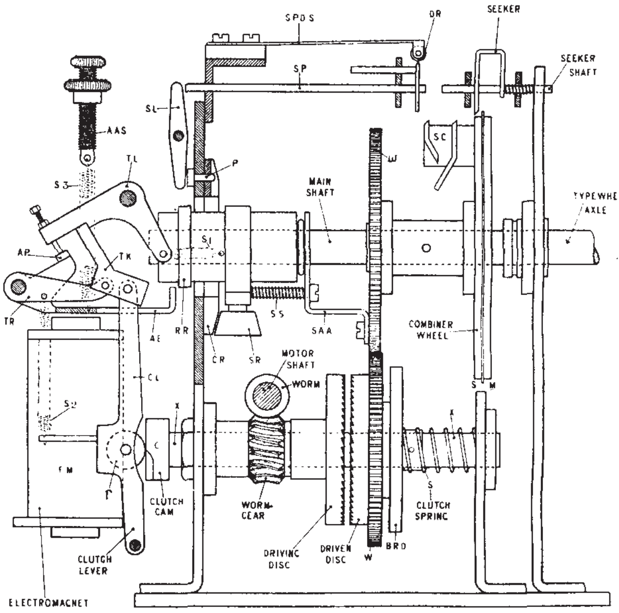


FIG. **6**.

The typewheel axle gears with the clutch spindle XX, which is normally at rest. When the armature of EM moves upward on the receipt of the " start " impulse, the armature projection AP trips the Toggle Latch TL and releases the Toggle TK. The clutch spring S then moves XX to the left and causes the clutch discs to engage in a similar manner to that described for the Transmitter. The " stop " impulse re-energises EM and the attraction of its armature allows TK to be re-engaged by TL. Cam C acting on roller *r* brings about the disengagement of the clutch discs and the typewheel shaft comes to rest after it has completed one revolution. A brake mechanism is provided to ensure that the rotating parts shall come to rest without undue shock.

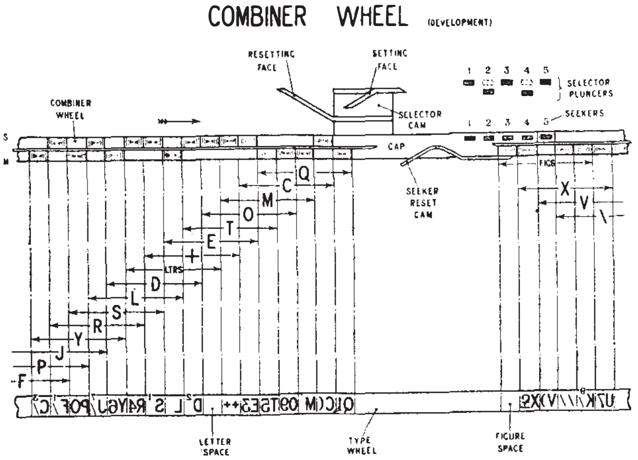


FIG. 7.

The movements of the armature, after its release by the " start " impulse, depend upon the incoming character combination of signals. They control the action of a shuttle roller SR, which rotates with the typewheel shaft. This roller presses on a circular cam ring CR under the action of spring SS. There are five indents in the surface of this ring and projecting through a hole in the bottom of each is a Selector Pin P. While the armature is in its attracted position, SR is free to drop into the indent over which it may be passing, causing the pin P to move backwards and actuate an associated Selector Lever SL. If, however, the armature is in its upward position, its extension AE comes behind the raised ring RR on the sleeve which carries SR, and thus prevents the latter from dropping into an indent. The corresponding selector pin and selector lever will not be actuated in these circumstances. This arrangement forms the mechanical distributor of the Receiver.

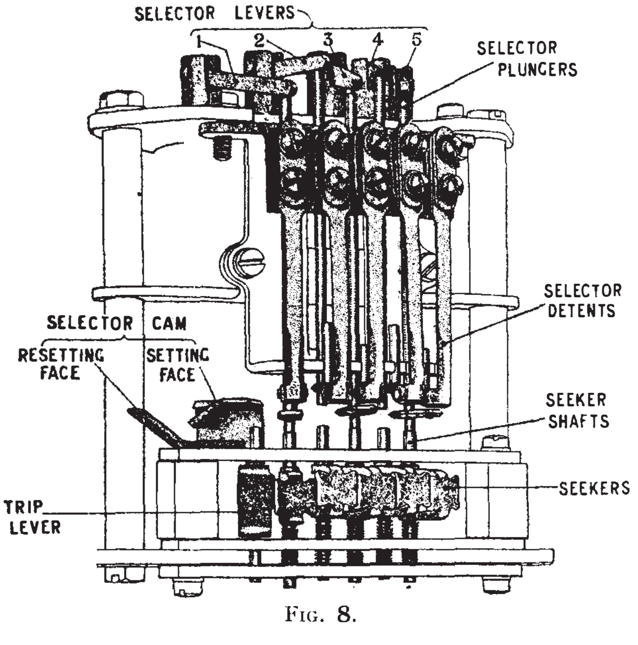


FIG. 8.

The five selector levers control five Selector Plungers SP, which in turn set five Seekers. Each selector plunger is held firmly in either of its two positions by a Detent Roller DR mounted at the end of a flat spring SPDS.

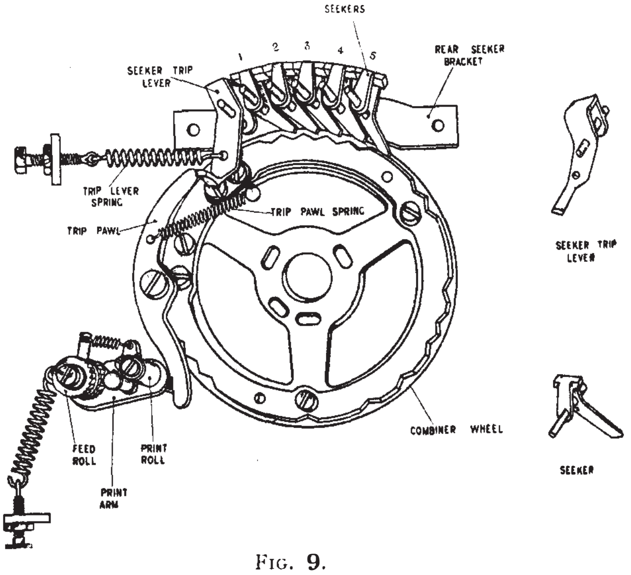


FIG. 9.

Setting of Seekers.—Mounted on the typewheel axle is the Combiner Wheel consisting of two discs S and M, between which is a Separator Plate. On the rims of S and M are cut, in definite positions, a series of notches, those on the front disc M representing marking units of the code and those on the back disc S spacing units. The arrangement of the notches (shaded) for several successive characters on the typewheel is shown in Fig. 7.

The five seekers with the aid of the combiner translate the incoming impulses into movement of a paper tape against the typewheel for printing the desired characters. Each seeker has a square flat head which presses against the heads of the adjacent seekers. Normally the toes of all the seekers press on the rim of disc S of the combiner, under the action of the Trip Lever Spring attached to the Trip Lever. The latter is pivoted in the same manner as a seeker and its head presses against the head of No. 1 Seeker (see Figs. **8** and **9**).

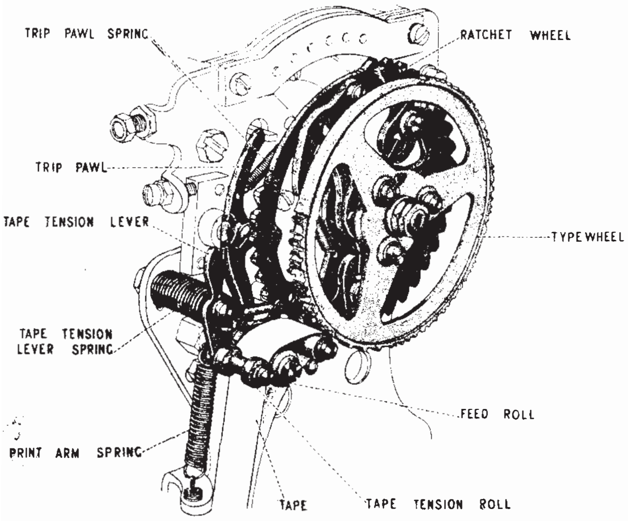


Fig. **10**.

When a character is being received, the five selector plungers are pushed forward, or not, according as the incoming impulse is a marking or a spacing unit. Fixed to the back of the combiner is the Selector Cam SC, and immediately opposite it there is a gap in the separator plate (see Fig. **7**). As SC moves with the combiner its setting face catches the lower end of a selector plunger, if it has been pushed forward, and forces it to strike the end of the shaft of the corresponding seeker. As the gap in the separator plate is, at this instant, passing the toe of the seeker, the latter is moved to disc M of the combiner. In this manner the five seekers are set, some being forced on to disc M and some allowed to remain on disc S according to the character being received. Immediately a seeker has been set, its selector plunger is restored to its normal position by the re-setting face of SC (see Fig. **8**).

Print Arm Release.—At a particular part of the revolution of the combiner, and therefore of the typewheel, there is for each character a combination of notches on the two discs, into which the toes of all the seekers can drop under the action of the Trip Lever spring (see Fig. **9**). The trip lever head moves to the right with the seeker heads and its lower end moves to the left, striking the Trip Pawl. The latter then disengages from a projection on the Print Arm, which accordingly moves in an anti-clockwise direction under the action of the Print Arm spring.

Paper Feed and Printing (see Figs. **10** and **11**).—A drawer is fitted in the base of the instrument to accommodate a roll of paper tape. The tape passes over the Tape Guide Post, round a Print Roller mounted at the end of the Print Arm and thence between a Feed Roller and a Tape Tension Roller. The Feed Roller is mounted on the same spindle as the Feed Ratchet and turns with it. When the print arm moves upwards on being released, the Feed Pawl engages with the Feed Ratchet causing it and the Feed Roller to turn and the tape to move forward with the Print Roller. While the print arm is being returned to its horizontal position the Check Pawl holds the Feed Ratchet and thus prevents the tape from moving back. Consequently the tape is fed forward on the Print Roller the space of one letter.

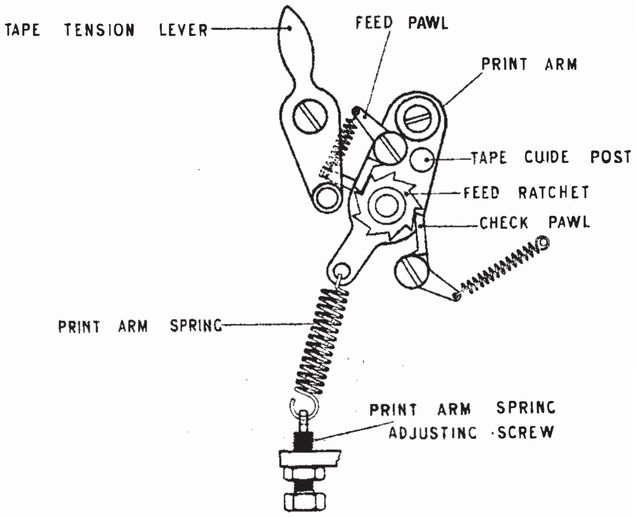


Fig. **11**.

Mounted behind the typewheel and on the same shaft is a Ratchet Wheel. When the Print Arm is released a pointed projection from it, termed the Print Dog, enters a notch in the Ratchet Wheel corresponding with the character to be printed, and is carried by the wheel to the left until clear of it. The tape is thus brought into rolling contact with the inked typewheel and the desired character is printed.

Immediately printing has been effected, the Re-set Cam attached to the front of the Combiner restores all the seekers to disc S. It should be noted that the Selector Plungers are set during one revolution of the Typewheel axle, but the seekers are set and printing takes place during the next revolution.

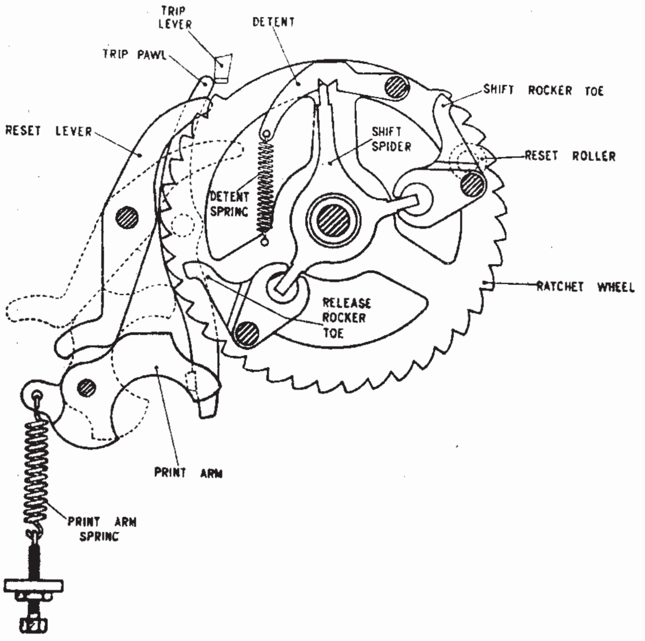


FIG. 12.

Re-setting of Print Arm (see Fig. **12**).—When the Print Arm is released it forces the lower end of the Re-set Lever to the left, thus moving its upper end so that it lies within the path of the Re-set Roller mounted on the back of the Ratchet Wheel. This roller subsequently acts on the upper end of the Re-set Lever, causing its lower end to move to the right and force the Print Arm back to the horizontal position where it is held again by the Trip Pawl. The re-setting of the Print Arm takes place during the time that the smooth portions of the rims of the typewheel and Ratchet Wheel are opposite the Print Arm in order to prevent the printing from being smudged and the Print Dog from fouling the Ratchel Wheel.

Shift Mechanism.—The typewheel has on its rim the letters of the alphabet alternated with figures and other secondary characters, amounting in all to 56 characters, but is normally in such a position on its axle that only letters are printed. It must be angularly displaced by about $4\frac{1}{2}^{\circ}$ in order that secondary characters may be printed. The Shift Mechanism is shown in Fig. **12**. The typewheel is fixed to a hub which is loose on the main shaft. A Shift Spider is attached to this hub and its pointed extension engages with one or other of two notches in a Detent fixed to the Ratchet Wheel. This provides the coupling between the Ratchet Wheel and the Typewheel.

When the spider engages with the left hand notch of the Detent, the typewheel is in its correct position for printing letters. If it is desired to print figures, the distant station sends the Figure Shift signal. The ordinary process of selection and release of the Print Arm occurs, but no printing takes place because the corresponding position on the Typewheel is a blank. The Print Dog, however, enters the space between two teeth of the Ratchet Wheel which is occupied by the Shift Rocker toe. The latter, which is pivoted on the Ratchet Wheel, will therefore be turned and will cause the Shift Spider to move from the left hand notch to the right hand notch of the Detent, thus displacing the Typewheel relatively to the Ratchet Wheel sufficiently to bring the secondary characters into the positions previously occupied by the letters. The change back to letters is effected by sending the Letter Shift signal from the Distant Station; in which case the Print Dog acts on the Release Rocker Toe, thus bringing the spider and therefore the Typewheel back to its normal position.

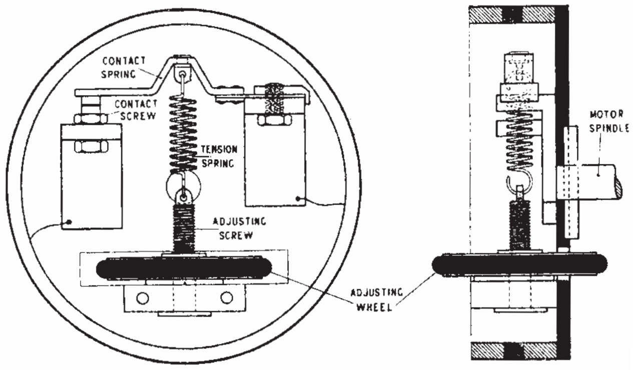


FIG. 13.

The Governor (see Fig. **13**).—The speed of the instrument is kept steady by a centrifugal governor mounted on one end of the spindle of the series wound driving motor. It consists of a hollow flywheel containing a contact spring, which, when it is held against a contact screw by the tension spring shown, short-circuits a governing resistance in the motor circuit. When the governor rotates, the speed increases until the centrifugal force acting on the contact spring is sufficient to cause the latter to move away from the contact screw, and immediately this occurs the governing resistance is inserted into the motor circuit causing the speed to decrease. The contact spring is accordingly pulled back to the contact screw and the short-circuiting of the governing resistance which results causes the speed to increase again. This making and breaking of the contacts take place very rapidly and an average speed is maintained depending on the tention of the controlling spring. The motor circuit is connected to the contacts by two carbon brushes which press on brass rings let into the periphery of the flywheel.

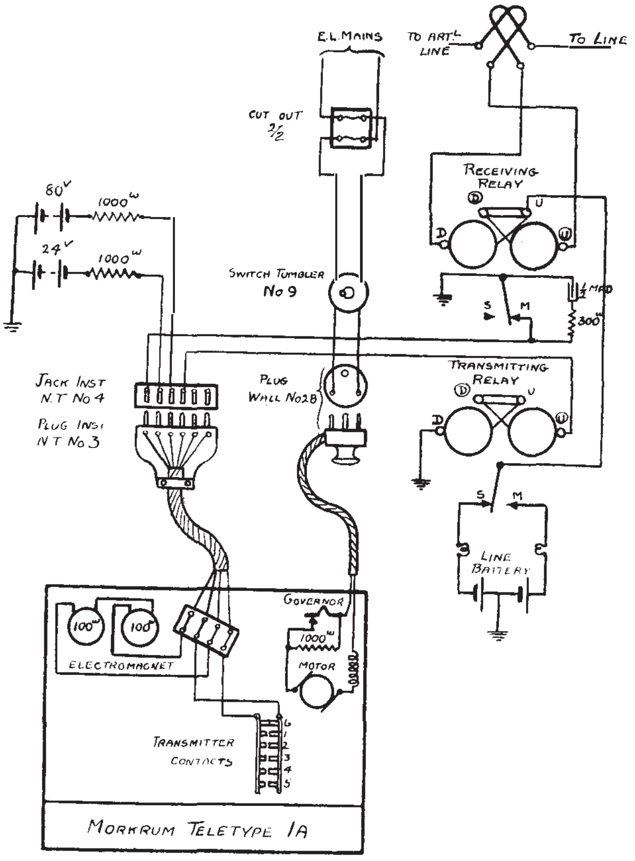


FIG. **14**.

The speed is set by observing the alternate black and white bands, painted on the edge of the flywheel, through slits in the shutters of a tuning fork. If the speed be correct the bands will appear stationary; if it be fast, however, the bands will appear to be moving in the direction of rotation; but in the reverse direction if the speed is slow. The speed may be decreased by slackening the tension spring by means of the adjusting wheel, or increased by tightening the tension spring.

Circuit Connections.—The majority of the circuits in this Country are worked duplex, the differential system being employed as shown in skeleton form in Fig. **14**; both ends are joined up alike. Two standard polarised relays are required, one for the reception of signals and the other for transmitting purposes. The Transmitting Relay is joined in series with the Transmitter Contacts and a 24 volt battery, and its tongue is held to the spacing contact, normally, because the sixth contact of the Transmitter is closed. The negative current thus sent to line passes through the D to U coil of the neutrally adjusted Receiving Relay at the distant station and holds its tongue to the marking contact. This closes the circuit through the electromagnet of the Morkum Teletype at that end. The home Receiving Relay is not affected because the outgoing current divides through it differentially. The Transmitting Relay at each end is set with a marking bias, so that it will respond to the breaking and making of the Transmitter Contacts when a key is operated and thus sends out signals to the line.

(*To be continued.*)

AN INTERNATIONAL TIME SIGNAL.

A. O. Gibbon, M.I.E.E.

THE linking together of the Royal Observatory at Greenwich with the Post Office Radio Station at Rugby for the distribution of Greenwich Mean Time is an event of outstanding interest.

Two hundred and fifty years have passed since the establishment of the Observatory in Greenwich Park in 1675. It was erected in the reign of Charles the Second and the terms of the original appointment are as follows:—

> " *Warrant for the Payment of Mr.*
> *Flamsteed's Salary.*
> Charles Rex.
>
> *Whereas, we have appointed our trusty and well-beloved John Flamsteed, Master of Arts, our astronomical observator, forthwith to apply himself with the most exact care and diligence to the rectifying the tables of the motions of the heavens, and the places of the fixed stars, so as to find out the so-much-desired longitude of places for the perfecting the art of navigation. . . . ."*

Now, in December, 1927, the direct distribution of Greenwich Mean Time to the whole world has become an accomplished fact, through the cooperation of the Admiralty, the Board of Trade and the Post Office.

This development is worthy of special consideration, seeing that, for the first time, a signal of extreme accuracy is available from the prime meridian for all who are able to receive it.

There is no need to emphasize the importance of an accurate time service. Practically all of the ordinary, everyday happenings in life depend upon correct time. If the postman be late with the morning mail;—if the newspaper boy finds some diversion on his round and the " Times " fails to be pushed under the door;—if the alarm clock fails to operate,—what a difference these minor things make in the outlook for the day! Our railway organization, also our telephone and telegraph services depend upon exact time keeping,—indeed, the list could be extended almost indefinitely — from personal to international spheres of action.

A digression from the main subject of this article will be excused, in order that reference may be made to the different measures of time in use at the present day.

Solar Time is the time registered by a correctly placed sun-dial. Solar time cannot be employed practically however, because the intervals from noon to noon are not of the same length, occasioned by the path taken by the earth in its motion round the sun. This variation is eliminated by a process of averaging and, as a result, *Mean Solar Time,* giving days of equal length, is obtained.

Sidereal Time, or star time, is the natural standard of time, a sidereal day being the time taken for one complete revolution of the earth on its axis. As a result, a particular star will cross the meridian of any place at intervals of 23 hours, 56 minutes, 4.1 seconds. This law applies because the stars are so far distant from the earth that the motion of the stars may be regarded as negligible. This is not the case with the sun, which is nearer the earth and results in the mean solar day being 3 minutes, 56 seconds longer than the sidereal day.

It is obvious, as a result of the earth's rotation, that the time shown on mean solar clocks will only agree with each other, where such clocks are set up in the same meridian. East or west of that meridian, the clocks will be fast or slow, varying with the longitude in which the clocks are working. Hence, there is a further measure in use known as *Local Time,* depending upon the place concerned. Local time has several serious disadvantages and these need not be stressed here.

The inconvenience caused by this measure of time led to its practical abolition in favour of *Standard Time.* This has been established by International agreement, whereby the whole world has been divided into " Time Zones," with the meridian of Greenwich as the prime meridian or " zero " point. As a result of this arrangement, *Greenwich Mean Time* is regarded as the standard for the world. The general scheme is that the minutes and seconds of the prime meridian are maintained and hours only are changed in successive time zones.

There is still *Summer Time* to be remembered, but as this movement of the hands of the clock forward or backward is merely a trick we play upon ourselves — for many good and sufficient reasons—there is no need to say more here!

Fig. **1** is a view of the South East side of the courtyard at Greenwich Observatory, showing the building containing the Transit instrument working on the prime meridian. The instrument is housed immediately behind the doorway reaching to the roof.

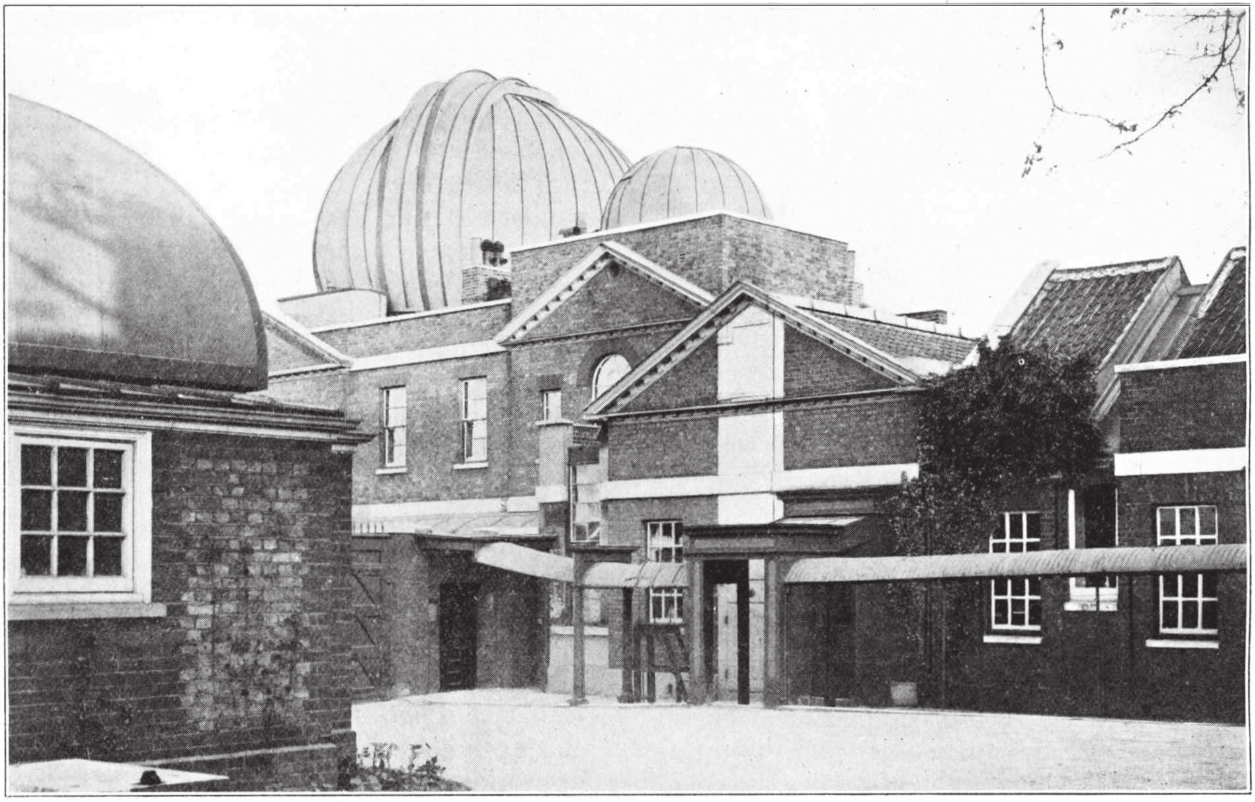


Fig. 1.—Greenwich Observatory building containing Transit Instrument working on prime meridian.

The large dome contains the biggest Refractor in the British Isles and is used for the measurement of double star working.

A general view of the exterior of a portion of Greenwich Observatory is shown in Fig. **2**. The famous Time Ball is clearly seen. It is mounted on the turret of the original Flamsteed building, erected in 1675. This Time Ball was set up in 1833 and was the first to operate in this country. The ball is released electrically and drops at 1 p.m. G.M.T. daily. The Time Ball is the most important of visible signals and is used by observatories to announce an exact moment of time to observers within visible range. The Time Ball at Greenwich has been in regular use since 1833 and the ball has dropped daily at the appointed hour, except on the very rare occasions when weather conditions have interfered and rendered it unsafe to lift the ball.

In order to introduce the International Time Signal, which is of the highest grade of scientific registration, it has been necessary to provide clocks and other mechanism at the Observatory, also for the Postmaster-General to provide the connecting lines between Greenwich and Rugby; special switching apparatus at the General Post Office in London and also the use of the wireless transmitter at Rugby.

A special chamber has been adapted at the Observatory for the accommodation of the apparatus. The high grade mechanism at Greenwich has been supplied by the Synchronome Company, under the personal direction of

Mr. F. Hope-Jones, a great authority on electrical clock installations. The apparatus consists of a " Free Pendulum," a " Slave " clock and a Signal Transmitter.

A general view of the chamber and the assembled apparatus is shown in Fig. **3**, whilst a closer view of the intricate mechanism of the Signal Transmitter is shown in Fig. **4**.

In clock mechanism as generally designed, there is a certain lack of exactitude due to the energy lost by the pendulum in having to unlock some form of mechanism before it can receive the impulse required to maintain its action. These operations rob the pendulum of a certain amount of energy and consequent lack of precision for scientific time keeping.

Fig. **2**.—Time Ball at Greenwich Observatory.

By means of an ingenious invention of Mr. W. H. Shortt, M.Inst.C.E., in conjunction with the Synchronome Company, a " Free Pendulum " has been devised. In this arrangement, a separate and subsidiary clock known as a " Slave " undertakes all the work and at the same time the " Slave " is so accurately controlled by the Free Pendulum that perfect synchronism between the two sets of mechanism is maintained. Air friction has also been practically eliminated from the Free Pendulum by enclosing it in an air-tight case and reducing the air pressure inside the case from the normal atmospheric pressure to a working point of approximately 35 milli-metres. The pendulum of this clock is made of Invar, an alloy having a very minute co-efficient of expansion with temperature changes.

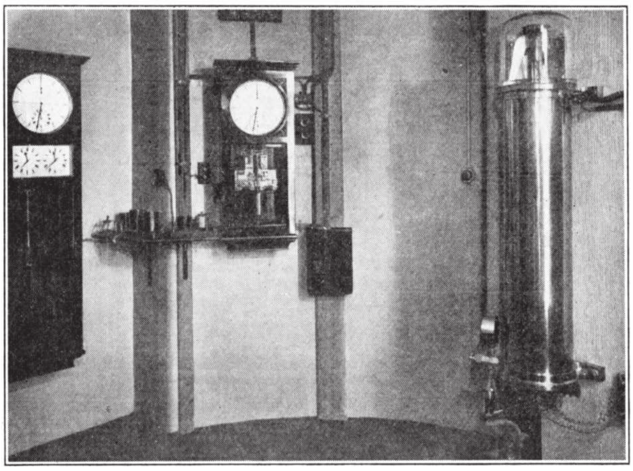


Fig. **3**.—Special Apparatus at Greenwich Observatory for International Time Service.

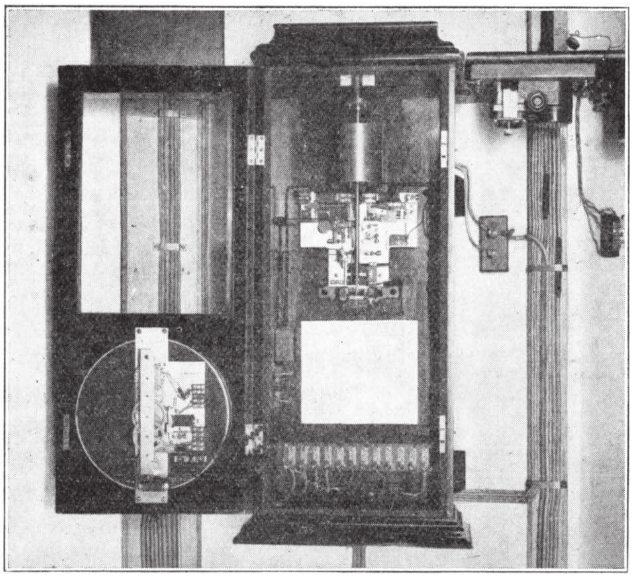


Fig. **4**.—View of mechanism of special Signal Transmitter at Greenwich Observatory used on International Time Service.

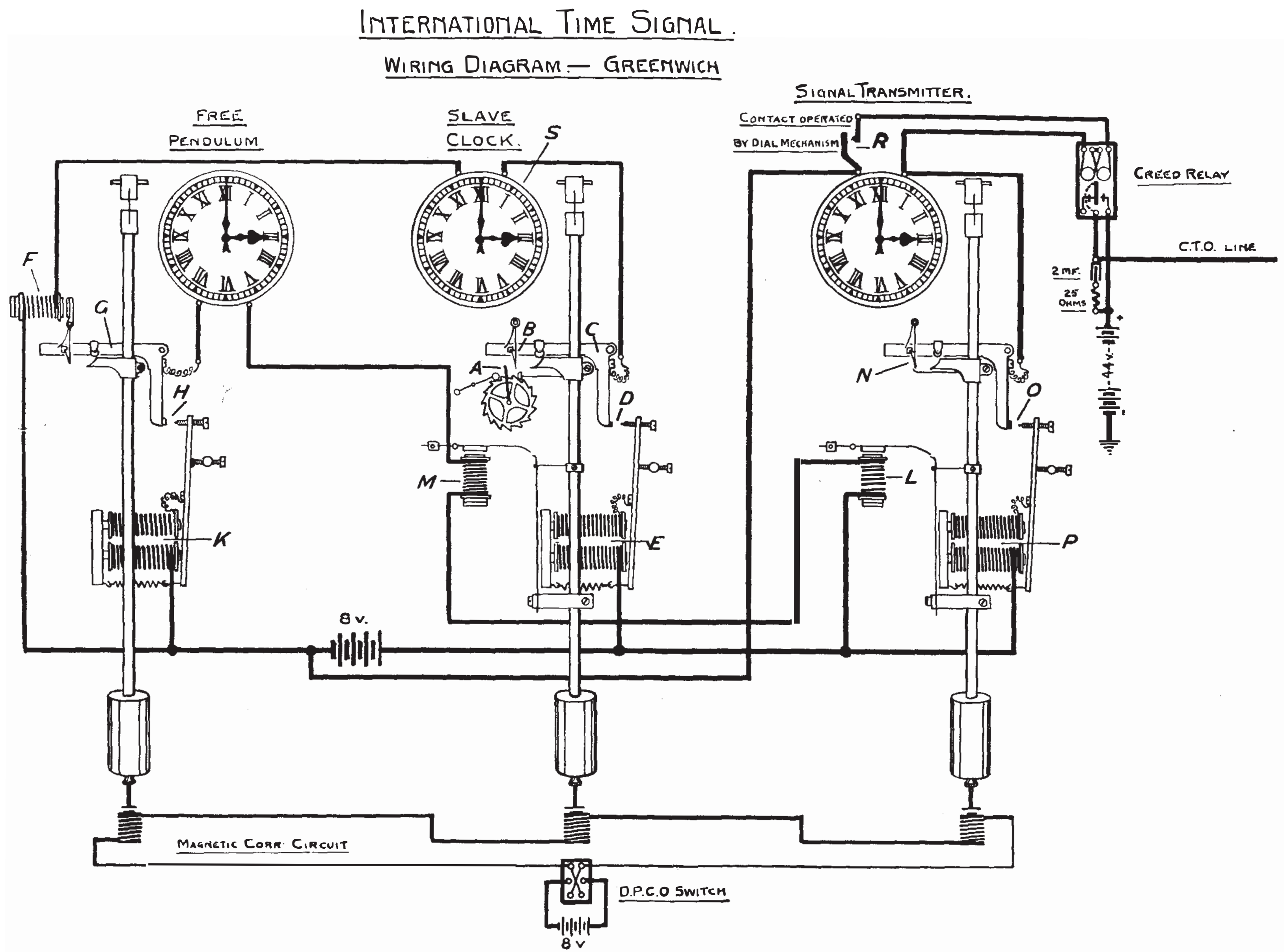


FIG. 5.—SCHEMATIC DIAGRAM OF THE CONNECTIONS OF FREE PENDULUM, " SLAVE " CLOCK AND SIGNAL TRANSMITTER USED ON THE INTERNATIONAL TIME SERVICE AT GREENWICH OBSERVATORY.

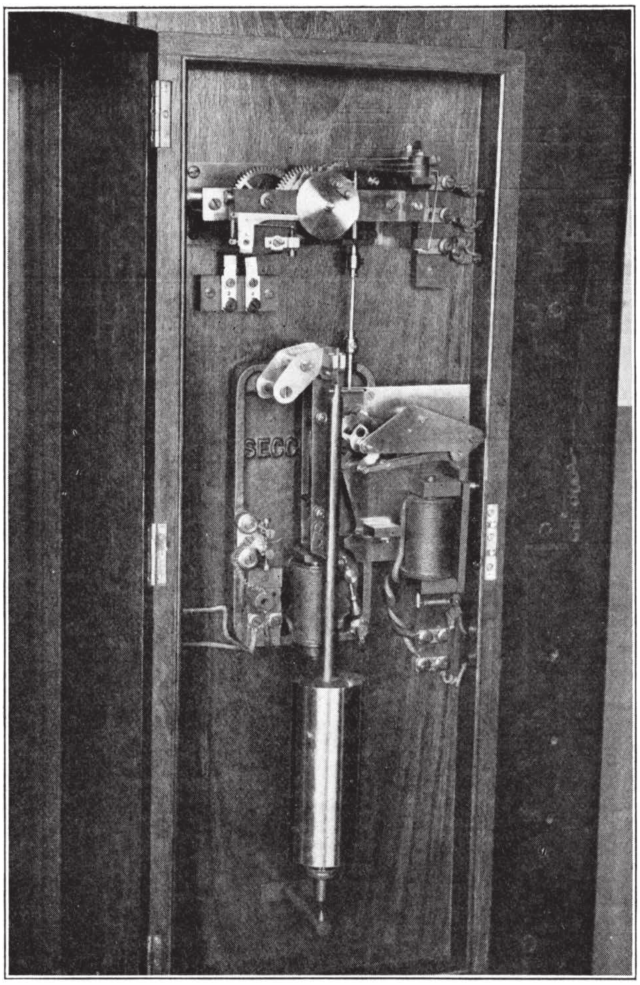


Fig. 6.—View of mechanism of special Time Switching clock in G.P.O. Test Room, used on International Time Service.

Fig. **5** is a skeleton diagram of the connections of the Free Pendulum, the Slave Clock and the Signal Transmitter at Greenwich. The action is as follows:—In the Slave Clock, the pendulum, in swinging to the right, pulls round the count wheel, and at each revolution of this wheel, the arm A. engages with the small trigger B. The trigger is opened, allowing the impulse lever C to fall, thus giving an impulse to the pendulum by sliding down the inclined plane. At the end of the fall of the impulse lever C, the contact D is closed. The electrical circuit is therefore from D through the electro-magnet and armature E, *via* the battery, electro-magnet release of the Free Pendulum F, back through the dial indicator of the " Slave " clock S.

The current in passing through E, pulls over the armature and re-sets the impulse lever C, also releases the trigger holding the impulse lever G of the Free Pendulum and puts the fingers of the Slave dial S forward one ½ minute. The cycle of operations in the Free Pendulum corresponds with that explained in the case of the Slave clock.

The impulse on re-setting the lever of the Free Pendulum is as follows:—When contact is made at H, the current flows through the armature and coil K, *via* the battery to the Synchronizer L of the Signal Transmitter, also the Synchronizer M of the Slave clock, completing the circuit through the dial mechanism of the Free Pendulum.

The object of this Synchronizing arrangement is to keep all three clocks in exact phase. It should be added that the contact H closes at a definite time interval after the impulse is given, in order that the synchronizing action may occur at a suitable position in the swing of the Slave pendulum.

The Signal Transmitter receives an impulse every alternate swing of the pendulum by means of the gathering click N; this releases the trigger in a manner similar to that of the Slave clock.

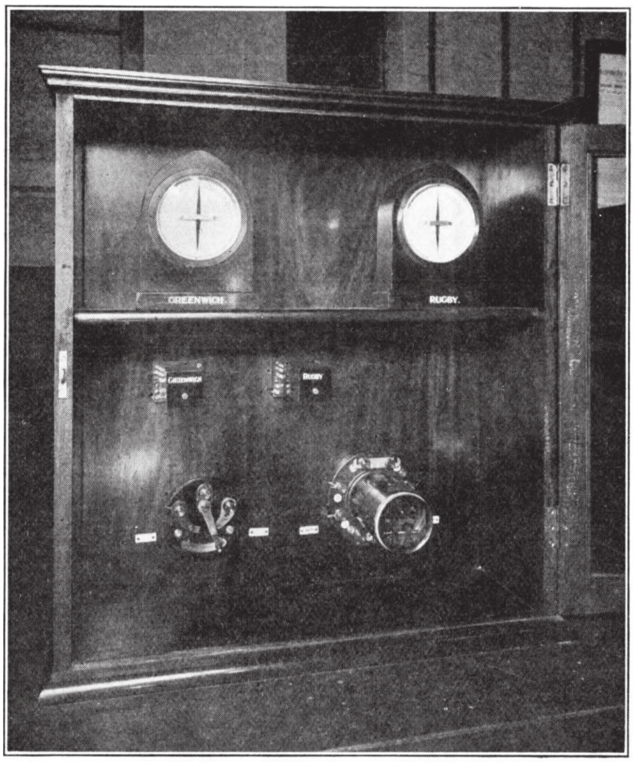


Fig. 7.—Switching panel used for International Time Service in G.P.O. Test Room.

The electrical circuit, after the impulse is given, is *via* the impulse lever, contact O, armature and electromagnet P, *via* the battery to the dial mechanism of the Signal Transmitter and, if the contact arm R is closed, through the transmitting Creed Relay, operating the C.T.O. line on its local contacts.

The Magnetic Corrector is shown at the bottom of Fig. **5** and is put into operation when it is necessary to set the three clocks to time. Its action is to increase or decrease the gravity action on the pendulum for a short period.

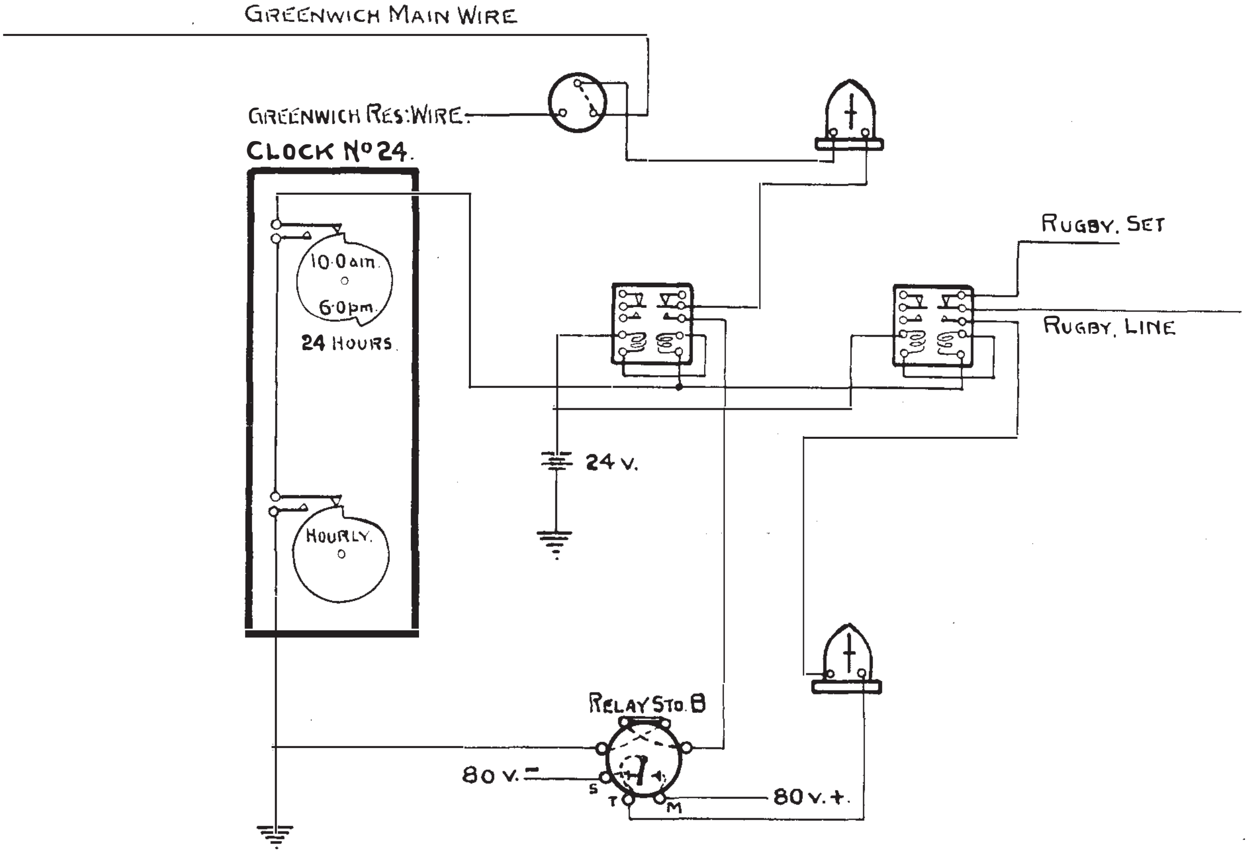


FIG. **8**.—SCHEMATIC DIAGRAM OF THE APPARATUS IN USE FOR INTERNATIONAL TIME SERVICE IN G.P.O. TEST ROOM.

The apparatus in use in the Test Room of the G.P.O., London, is shown in Figs. **6** and **7**.

Fig. **6** is a view of the Master Clock (No. 24) and Fig. **7** is a photograph of the switching panel.

A schematic diagram of the connections at the G.P.O. is shown in Fig. **8**. There are two cams fitted in the Master Clock; the front one revolves once hourly and the rear cam revolves once in every 24 hours. The rear cam registers the hours and the front cam the minutes. The cuts or slots in the cams operate the contacts at the appointed times in morning and evening and energise the two Relays No. 90A, which act simply as locking devices on the Greenwich and Rugby sides, taking the apparatus side of the Rugby line from the Central Radio Office and putting the Greenwich Observatory line through direct to the Rugby Radio Station. The Time Signal passes through the coils of the standard B relay on the switching panel, bringing the local contacts of the relay into play and applying the necessary voltage to operate the land line apparatus of the Rugby transmitter. The arrangements at Rugby Radio Station are shown diagramatically in Fig. **9**, where the normal arrangements for wireless transmission apply. The same apparatus is in use at Rugby as is required for commercial traffic. The Time Signal is sent out from Rugby on a wave-length of 16 kilo-cycles or 18,740 metres.

Several interesting problems concerning the extent and effects of mechanical and line lags, etc., have been investigated in connection with the new time signal. The physical circuit includes an underground line from Greenwich Observatory to the G.P.O., a standard B relay in the G.P.O. test room, an underground line from the G.P.O. to the Rugby Radio Station and the operation of two relays (1 standard B; and 1 Creed), also the operation of the large group of valves in the radio transmitting circuit.

The total lag measured through the whole of this network amounts to 0.04 second and the lag has remained practically constant. This stability has been an unsolicited testimonial to the behaviour of the relays, which have been called upon to work to a degree of exactitude beyond their ordinary range of action.

The presence of this lag involves the sending out of the time signal from Greenwich Observatory .04 second in advance of exact time in order that the signal may be emitted at the right instant. An arrangement has also been set up at Greenwich whereby the signal emitted from Rugby is registered on a syphon recorder associated with a Wireless Receiver at the Observatory. Normally, the incoming signal at Greenwich is recorded within .01 of a second of the time calculated for the emission of the signal.

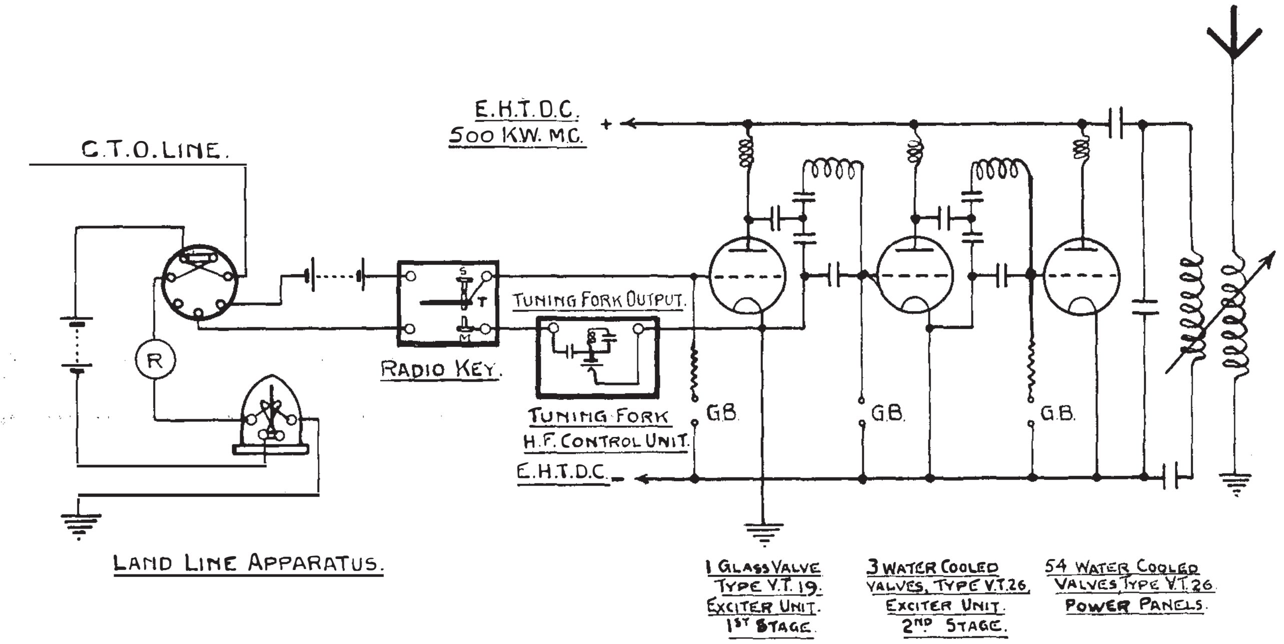


FIG. 9.—SCHEMATIC DIAGRAM OF THE ARRANGEMENTS AT RUGBY RADIO STATION.

The time signal is of the modified rhythmic type recommended by the International Time Commission of 1925. This consists of a rhythmic signal of 306 beats or dots (.) in 300 seconds of mean time, or at the rate of 61 beats or dots per minute. The commencing signal, also that at the end of each minute, is sent in the form of a dash (—) and is exactly on the minute of Geenwich Mean Time.

The signal is sent twice in each day, at 09.55.00 in the morning and at 17.55.00 in the evening. These times have been selected as the most suitable for reception in any part of the world. Signals 1, 62, 123, 184, 245 and 306 are single dashes of 0.4 second duration and commence at the exact minute. Each dash is followed by 60 dots of 0.1 second duration. By the use of this type of signal, comparisons of extreme accuracy are obtained, the method employed being to count the number of intervals from the first dash until coincidence occurs between one of the rhythmic signals and the beat of the chronometer or other type of clock.

A similar type of signal is sent out daily from Bordeaux and the Eiffel Tower. In each of these cases, and at other stations emitting a similar signal, a preliminary warning or prefix is sent, giving the station of origin, also a signature or " SN " at the end of the signal.

This procedure is not followed with the British Time Signal. The connecting lines between the Observatory and Rugby are switched over automatically a few moments before the signal is due to commence and are also retained for a few moments after the signal has passed. The interruption to commercial traffic, together with the short periods of silence, are the only indications of the approach and termination of the time signal. This is a departure from the usual method of signalling " CQ, CQ, DE, DE, GBR, GBR," to warn listeners to be ready, nor do we hear such a cheerful signature as that frequently given by the Annapolis station, " OK NSS," at the conclusion of the American time signal.

In concluding this review of an interesting engineering operation, the writer wishes to express his appreciation of the valuable assistance rendered to him by Sir Frank Dyson, the Astronomer Royal, and also by Mr. W. Bowyer, of the Greenwich Observatory Staff.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

TELEPHONES AND WIRE MILEAGES, THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 31ST DEC., 1927.

No. of Telephones owned and maintained by the Post Office.	Overhead Wire Mileage.				Engineering District.	Underground Wire Mileage.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
565,641	538	4,113	52,344	181	London	23,698	64,367	2,140,885	104,065
71,280	2,122	21,076	63,611	1,719	S. East	3,870	44,358	175,733	14,567
75,373	4,406	30,259	53,071	2,491	S. West	18,179	10,889	135,063	59,238
58,926	6,037	37,039	56,020	4,985	Eastern	22,210	34,559	92,510	75,512
92,326	8,799	44,763	56,505	3,583	N. Mid.	23,138	50,426	231,628	119,973
72,868	4,825	29,085	68,924	4,058	S. Mid.	13,117	21,670	158,566	89,307
56,267	4,680	29,288	50,515	2,841	S. Wales	5,992	25,565	105,604	70,275
98,195	8,225	26,163	48,331	4,361	N. Wales	13,254	40,513	250,459	62,143
150,978	1,564	17,043	42,551	2,523	S. Lancs.	13,117	76,344	451,512	47,087
89,157	6,113	30,894	45,765	3,100	N. East	11,067	44,283	214,488	61,435
61,255	3,512	23,595	36,654	2,351	N. West	8,180	32,469	153,837	37,398
45,414	2,460	15,989	24,184	2,748	Northern	4,639	14,677	98,766	51,451
20,638	4,680	8,313	13,521	491	Ireland N.	130	2,306	36,770	1,211
62,794	5,472	24,943	36,190	1,478	Scot. East	3,640	12,021	142,723	47,643
84,489	7,336	23,968	42,319	1,047	Scot. West	12,101	24,493	215,548	35,034
1,605,601	70,769	366,530	690,505	37,957	Totals.	176,404	498,940	4,604,092	876,339
1,575,766	70,820	362,202	683,405	37,207	Figures at 30th Sept., 1927.	174,550	492,207	4,460,068	900,744

TELEPHONES

HOLBORN.

IN the previous issue of the Journal it was indicated that some technical details of the system would be given. The object of the notes that follows is in general terms to outline the salient features of the *Director* equipment.

The underlying principles of Director working are now well known, but it may be well to emphasise that the main reason for introducing the system into large networks such as London is to enable routing and numbering to be dissociated, thus permitting the use of a freely flexible trunking scheme; hence the existing cabling arrangements may be used to the maximum advantage. It follows also that indirect routing *via* a Tan-

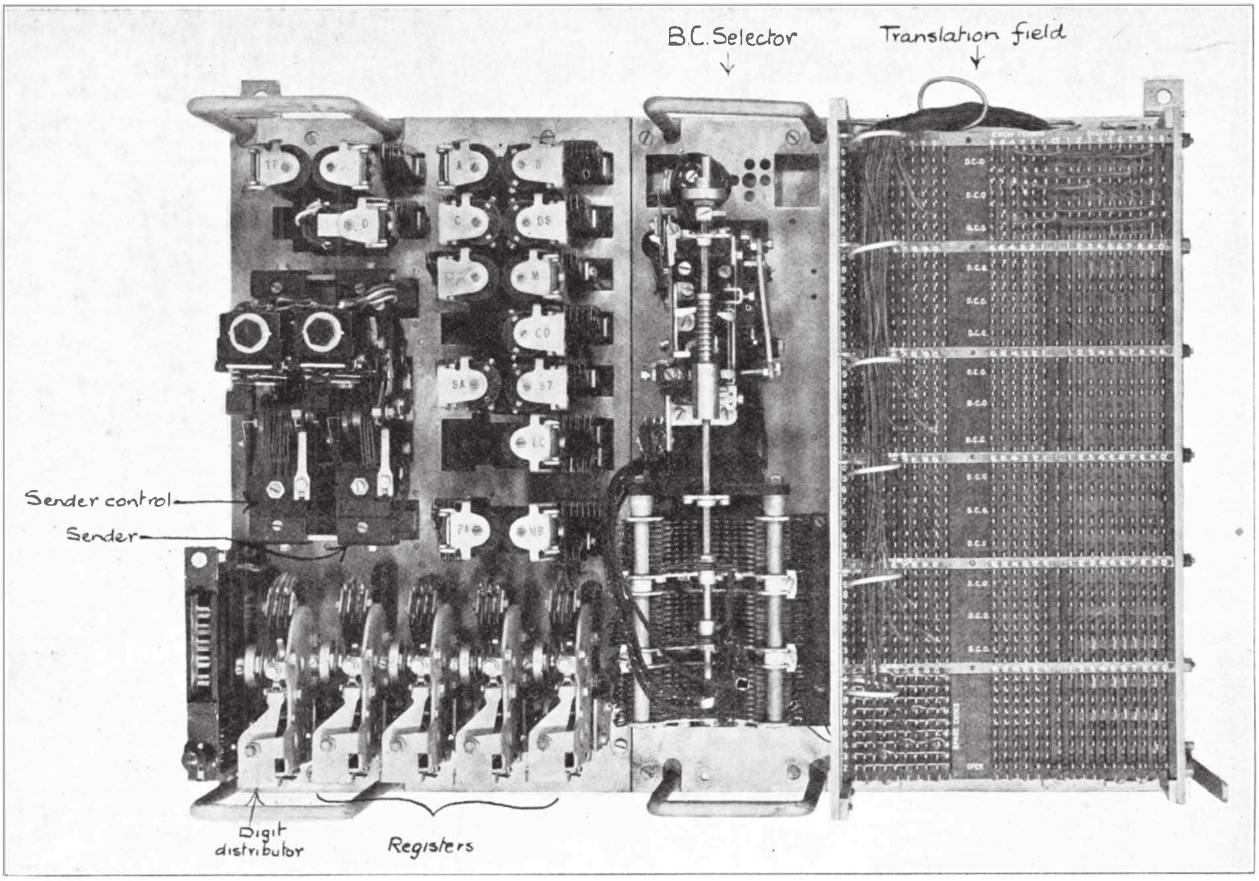


Fig. 1.—A Director.

dem switching point is possible. The function of the *director* apparatus therefore is "to convert the impulse trains of the code letters dialled by a subscriber into other impulse trains suitable in number to direct the call to the required exchange, *i.e.*, to translate the call. The *director* and associated equipment is thus in use only during the setting up of a call, the average occupation time being 18 secs. per call.

Fig. **1** shews a director as installed in Holborn Exchange, and is typical of those to be used generally in the London system.

Fig. **2** is a rack of directors. In Holborn and other early exchanges the *directors* are fitted back to back as shown in the illustration, but this type of construction may be modified in the light of experience and single sided racks used in later exchanges to provide better accessibility to the apparatus when dealing with faults *in situ*.

Fig. **3** is a schematic diagram that indicates the relative position of the various selectors in the scheme; the figure clearly shows the relationship between routing and numbering. The selectors used, with the exception of the A digit and first code selectors, are standard two-motion switches and do not call for special comment. The A digit selector, from the levels of which *directors* are reached, is fundamentally similar to the standard selector, but has a "time pulse" feature associated for the purpose of "forced release" when the selector is seized but not operated; the principle of the "time pulse" arrangement will be seen from Fig. **4**. As the operating current (time pulse earth) is connected for 1 second at 30 second intervals, the "forced release" relay (M in sketch) will be operated in approximately 29 seconds as a minimum, or approximately 59 seconds as a maximum.

The disposition of *directors* on the levels of A digit selectors is shown in Fig. **5**, from which it will be seen that level 1 is not connected (there are no letters in the digit hole of the dial containing the figure 1), the selector therefore releases if it be inadvertently operated to the first level. Level O is not provided with individual *directors*, but makes use of *directors* on other levels. The connection between the bank contacts of level O and the bank contacts of the selected levels is reversed to enable the operation of the scheme shown in Fig. **6**. The *directors*

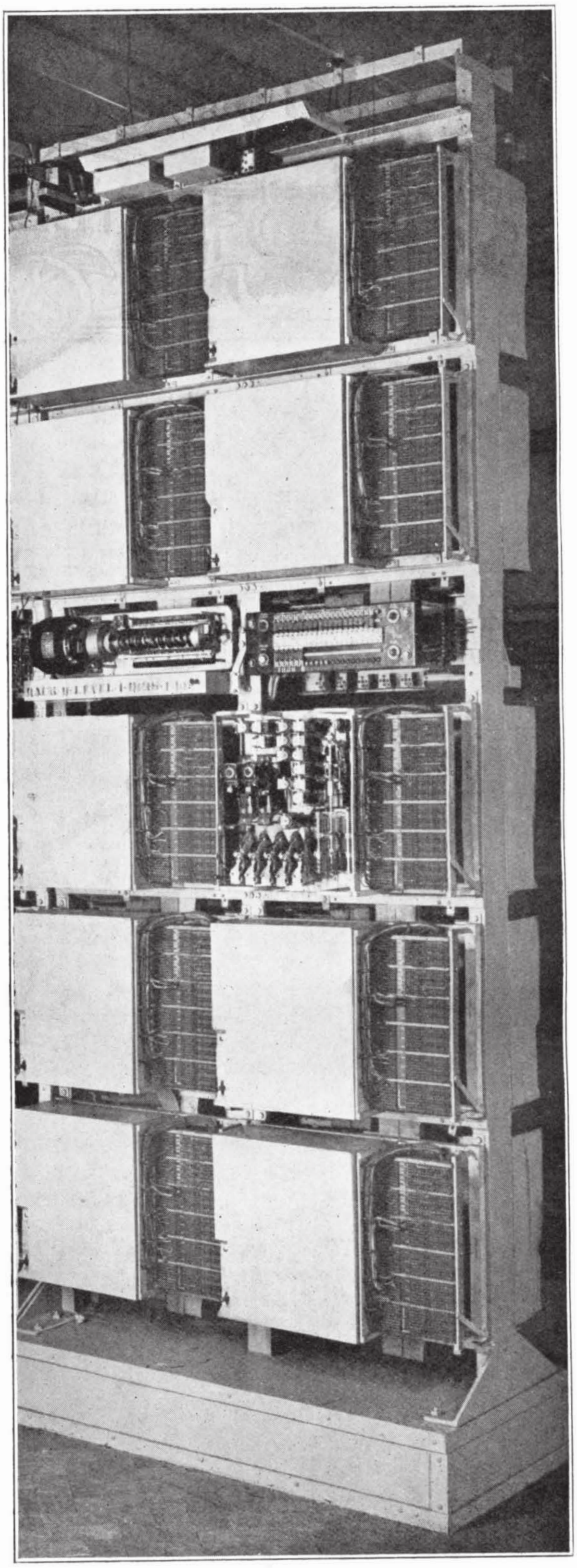
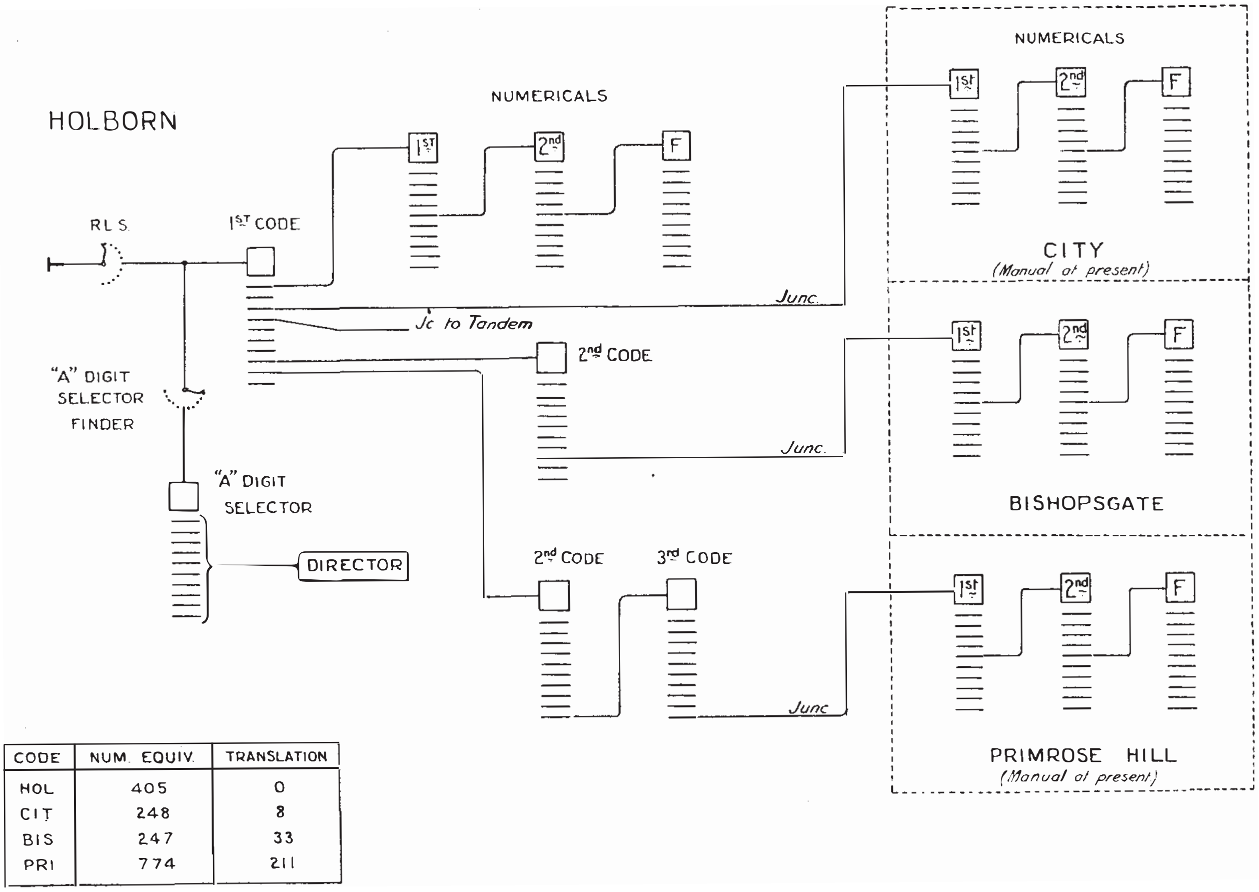


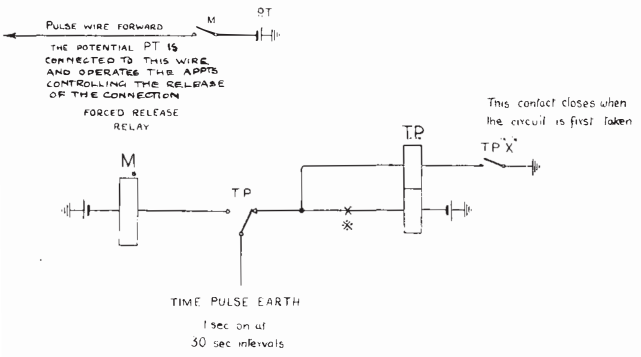
Fig. **2**.—A rack of Directors.



CODE	NUM. EQUIV.	TRANSLATION
HOL	405	0
CIT	248	8
BIS	247	33
PRI	774	211

FIG. 3.—SCHEMATIC DIAGRAM SHOWING RELATIVE POSITION OF SELECTORS.

reached from level O are provided with a special relay MB, which is energised only when the shunt field relay D is operated. This occurs when the direction of the current through its operating winding is reversed, (hence the reversal of wires between level O bank contacts


PULSE WIRE FORWARD
M
PT
THE POTENTIAL PT IS CONNECTED TO THIS WIRE AND OPERATES THE APPTS CONTROLLING THE RELEASE OF THE CONNECTION
FORCED RELEASE RELAY
This contact closes when the circuit is first taken
T.P.
TP"X"
M
TP
※
TIME PULSE EARTH
1 sec on at
30 sec intervals

※ This connection (either relay contact or OFF NORMAL contact) closes when the switch is seized and is opened if the switch operations are proceeding normally

FIG. 4.—THE PRINCIPLE OF THE TIME IMPULSE.

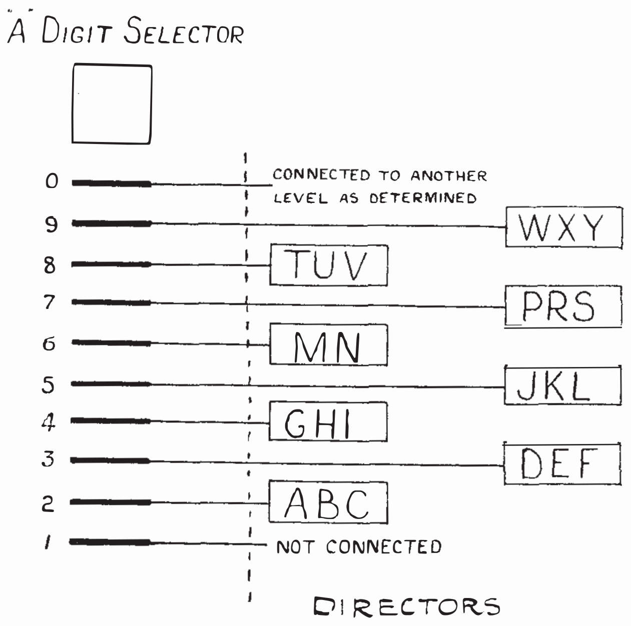


FIG. 5.—DISPOSITION OF DIRECTORS ON LEVELS OF A DIGIT SELECTORS.

and the bank contacts of the selected level). The operation of relay MB thus gives access to the translation field without the need for transmitting second and third code letters (B C digits).

The first code selector, as will be seen from Fig. **3**, is in use for every class of call, regardless of its ultimate destination. It incorporates a transmission bridge which makes it unnecessary to provide relay sets (repeaters) in the junction circuits connected to the bank contacts. Full supervision is provided by the selector, which is also used to advise subscribers of irregularities and fault conditions as indicated in the following schedule :—

Nature of Abnormal Condition.	*Resultant Effect.*
Subscriber dials prematurely (*i.e.* all "A" digit switches busy).	Caller receives N.U. tone.
Apparatus or line fault engaging on A digit selector.	(*a*) A digit selector released in 29-59 secs. (*b*) Faulty line connected to 1st code selector, lamp glows.
Subscriber removes receiver and delays to dial.	(*a*) A digit selector released in 29-59 secs. (*b*) Sub. left on 1st code selector. (*c*) When sub. dials N.U. tone given.
Subscriber dials a portion of the code and then delays.	(*a*) A digit selector and Director released in 29-59 secs. (*b*) 1st code selector transmits N.U. tone to subscriber.
Subscriber dials the code and then delays.	The translated code impulses have passed out, code selectors have operated and a 1st numerical selector has been taken. (a) A digit selector and Director and all selectors except the 1st code released and the junction freed in 29-59 secs. (b) 1st code selector transmits N.U. tone to subscriber.
Subscriber dials code and a portion of the numerals.	As above including the release of the numerical selectors that have been operated.
Subscriber dials non-existent code.	(*a*) A digit selector and Director released immediately. (*b*) 1st code selector transmits N.U. tone to subscriber.
Director seized, but impulsing equipment fails to function.	(*a*) A digit selector and Director released immediately. (*b*) 1st code selector transmits N.U. tone to subscriber. (*c*) Director made "busy." (*d*) Director supervisory lamp flashes until attention is given.

As is generally known, the impulses passed into the switching network from *directors* are derived from machine operated cams. Fig. **2** shows an impulse machine in position on the

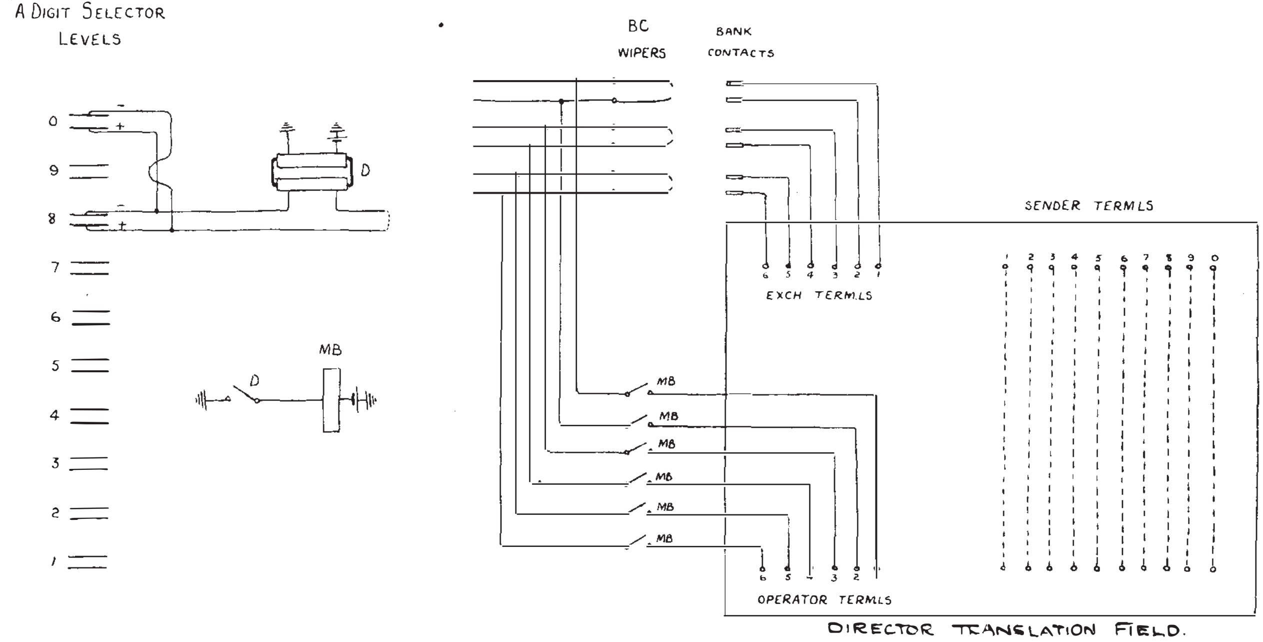


FIG. **6**.—SHOWING REVERSAL OF BANK CONTACTS OF LEVEL O, SHUNT FIELD RELAY AND SPECIAL RELAY MB.

rack and Fig. **7** is a separate view of a typical machine. At Holborn one such machine serves 10 directors, 5 back and 5 front. As the directors serving a particular A digit selector level are located on one side of the rack, the rack impulse machine thus serves a portion only of the *directors* associated with different levels, so that the failure of a machine does not result in the breakdown of the whole of the directors associated with a specific A digit selector level. The Holborn machines are designed for speed regulation by means of a centrifugally governed slipping clutch, so that the speed of the cam shaft is maintained at 600 R.P.M.; thus impulses are delivered at an uniform rate of 10 per second.

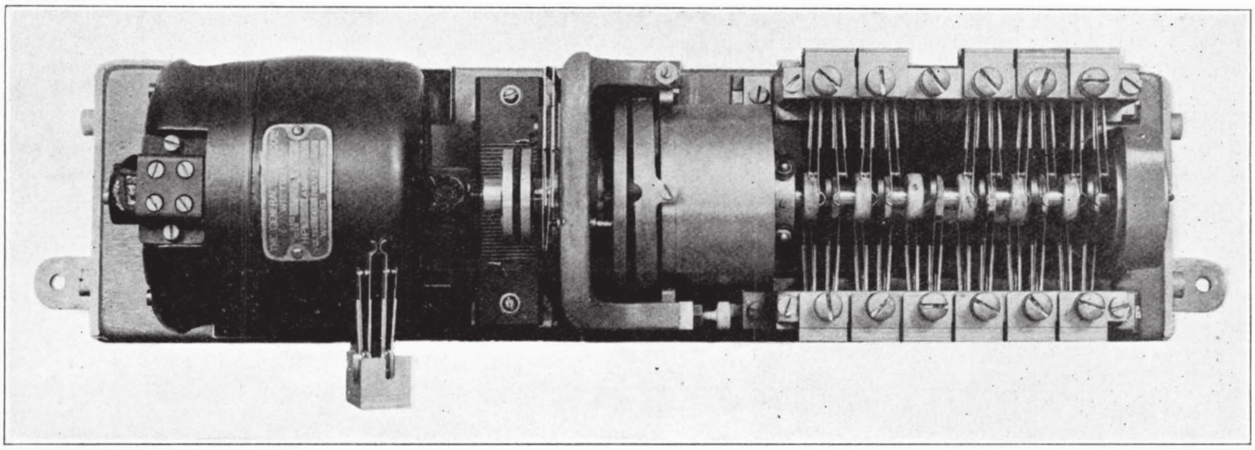


Fig. **7**.—An Impulse Machine.

As each *director* requires two sets of interrupter springs, the machine is provided with 20 cams (spring sets), 10 sets adjusted to deliver impulses having ratio "break" to "make" 2 : 1, and 10 sets with ratio "break" to "make" 1 : 2. The former type of impulse is required to operate selectors and the latter to step the sender switch of the director. As the result of synchronism between the two types of impulses the sender steps during the period when the selector magnet is operated and the shaft is "stepping." The sender "counts" the number of impulses transmitted to the selector network, the actual impulses, as already indicated, being derived from impulse cams. The method of controlling the series of impulses supplied is shown schematically in Figs. **8** and **9**. When the sender switch steps initially, relay SA (Fig. **8**) is operated *via* one of the sender arcs, a contact of SA connecting the "line" cam to the outgoing portion of the circuit; when the sender wiper reaches the contact marked (*via* digit distributor, sender control switch, BC digit switch wiper, No. 1 contact of sender bank in Fig. **9**) relay SZ operates, a contact of which short-circuits the cam, thus stopping the supply of further impulses. Subsequent operations cause the sender control switch wiper to step to the next contact. The sender switch returns to a "home" position and again starts the cycle of operations. This process continues until the whole of the necessary impulses are passed out, when the director and A digit selector are released.

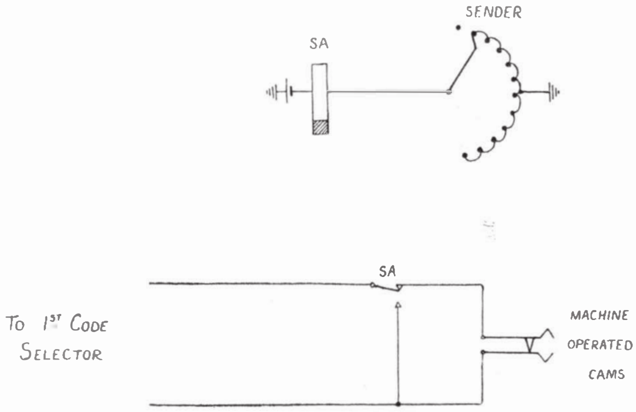
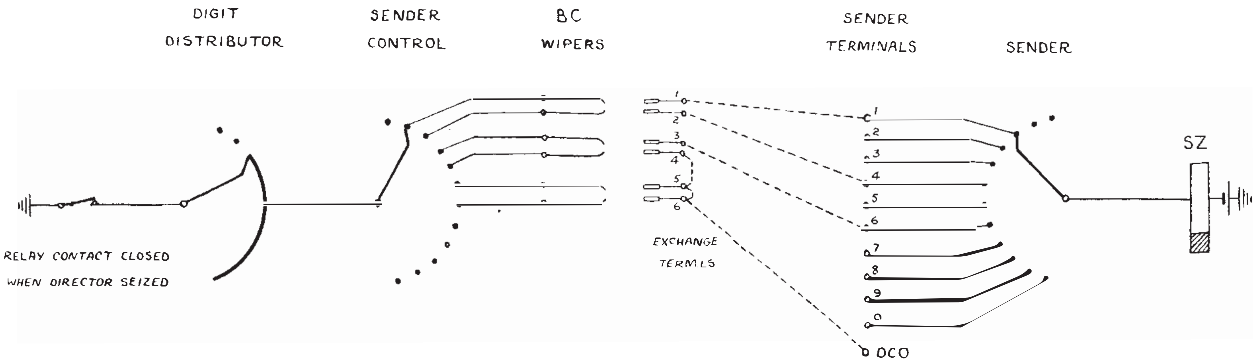


Fig. **8**.—Method of controlling series of impulses.

A "time pulse" feature similar to that described in Fig. **4** is provided to forcibly release the director in the event of delays arising or faults occurring when the apparatus has been seized.



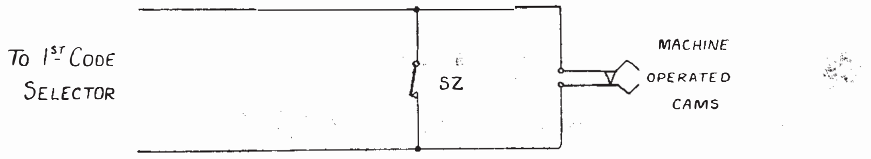


Fig. 9.—Method of controlling series of impulses.

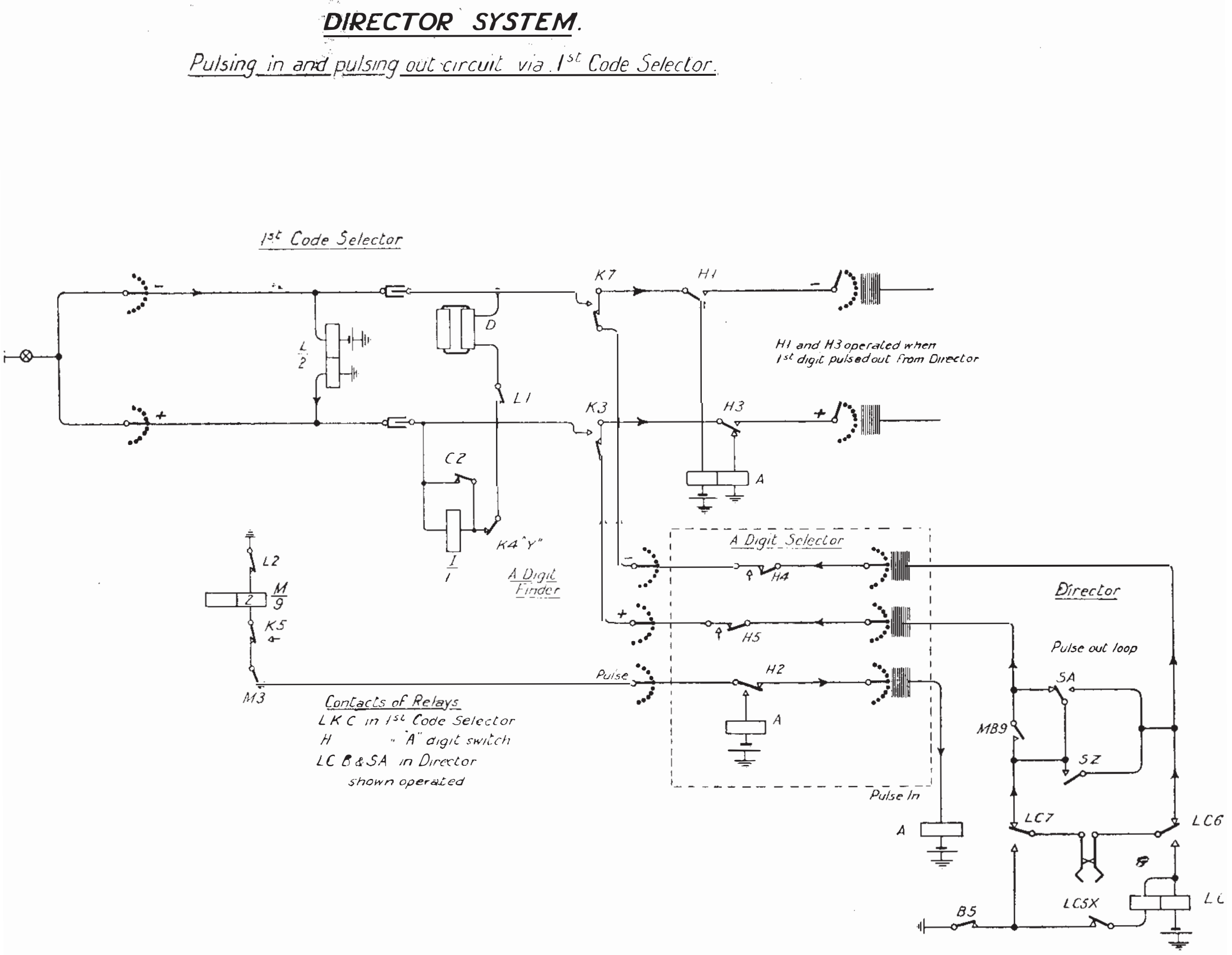


Fig. 10.—Elements of circuit during receipt and despatch of impulses.

No attempt has been made to explain the operation of the Holborn circuits in detail, but rather to indicate a few of the interesting circuit features. In subsequent issues of the Journal the apparatus used and the facilities afforded by it will be given.

Fig. **10** is interesting, and shows the "elements" of the circuit during the simultaneous receipt and despatch of impulses.

At the time of writing the Holborn apparatus is settling down to its job and is working smoothly. The Holborn staff are to be congratulated upon the efficient manner in which the apparatus is maintained and to them lies the credit of handling the first Director Exchange in what is probably the most complicated city telephone network in the world.

C.W.B.

HANLEY AREA AUTOMATIC TELEPHONE EXCHANGES.

W. Ireland, A.M.I.E.E.

At midnight, 26th November, 1927, practically the whole of the telephone system in the Hanley Multi-Exchange Area was successfully changed over to automatic working. Six manual exchanges, namely, Hanley, Longton, Newcastle-under-Lyme, Chesterton, Trentham and Wolstanton were closed down and seven automatic exchanges simultaneously brought into use along with the manual board at Hanley, the main exchange, to which all calls requiring the attention of a telephonist are routed by dialling the prescribed codes ("0" for trunk and junction calls to manual exchanges and "91" for inquiries, etc.).

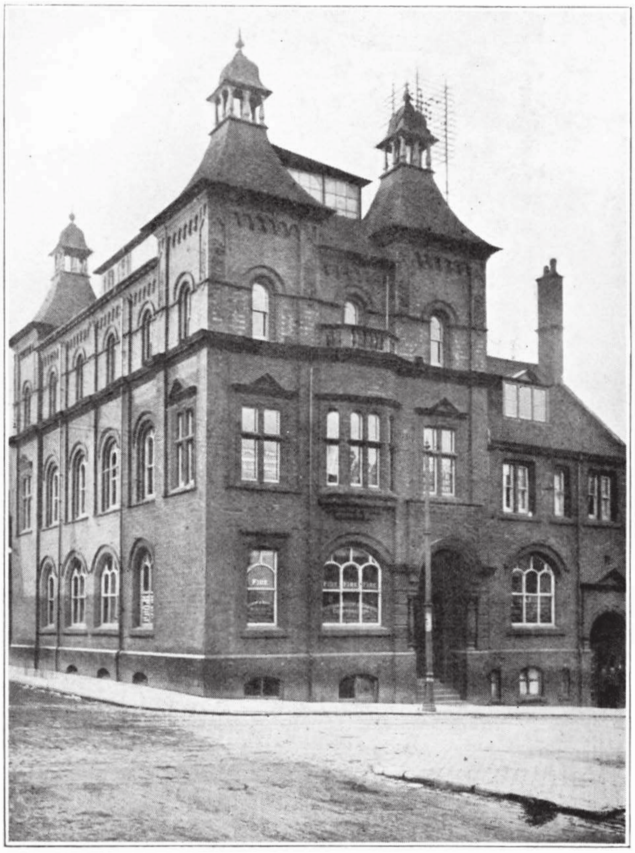


Fig. 1.—Hanley Building.

The superseded manual exchanges were worked on the call key, ring-through system and were the last exchanges of this type in the country. The old Hanley Exchange was brought into use in 1901, so has many years of useful service to its credit.

The exchanges in the automatic area with their present equipment, ultimate capacities, and numbering scheme are as follows:—

Exchange.	Present Equipment.	Ultimate Capacity.	Numbering Scheme.
Hanley	2,000	2,000	2,000—2,899 5,000—5,899 29,000—29,199
Burslem	1,100	2,200	7,000—7,999 8,000—8,799 88,000—88,399
Longton	700	1,100	3,100—3,899 39,000—29,299
Newcastle	700	1,000	6,100—6,699 67,000—67,399
Stoke	900	1,500	4,100—4,799 48,000—48,799
Trentham	200	500	49,000—49,499
Chesterton	100	200	68,000—68,199
Endon	Manual	400	29,000—29,399
Kidsgrove	Manual	500	89,000—89,499
Silverdale	Manual	500	69,000—69,499

The Hanley new equipment has been installed in the existing building which housed the old exchange, this building having been adapted to meet the requirements of the new apparatus, while all the other automatic exchange equipments have been accommodated in new buildings provided by H.M. Office of Works.

Fig. **1** shows the Hanley Exchange building. This was erected in 1900 by the National Telephone Co. and was the headquarters of the Potteries District staff. (This figure has been reproduced from an old photograph taken, as will be noticed, when part of the building was let.)

One old exchange in the area, Wolstanton, has been closed down and two additional exchanges, Burslem and Stoke, introduced, the lines which previously worked on the former having been transferred to Burslem, while the latter two exchanges have relieved Hanley of lines which it accommodated before the transfer. Also a few of the Longton lines have been transferred to Stoke.

Endon, Kidsgrove, and Silverdale, which are in the Automatic Area, are remaining as manual for the present, the intention being to convert them to automatic working later.

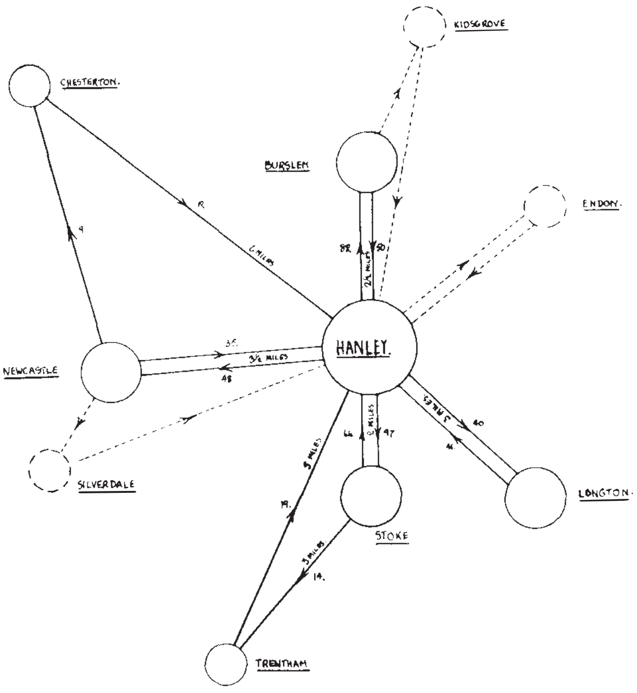
It will be seen from the above schedule that Burslem will ultimately be the largest exchange as regards number of subscribers' lines, but Hanley has been made the main exchange by virtue of its geographical position and thus contains all the first selectors for the area as well as those for manual exchanges outside the area which dial in.

The whole of the exchange equipments are of the Strowger step-by-step system adopted by the Post Office as standard for non-director areas, and were manufactured and installed by the General Electric Co. (Peel-Conner Telephone Works), Coventry.

The preselectors are of the homing type, which permits the outgoing trunks to the 1st selectors being graded, this grading being carried out on a special link frame, while the grading between the different ranks of selectors is done at the terminal assemblies associated with the selector racks.

Fig. **2** is a diagram of the Area showing how the various exchanges are connected by junctions, the number of working junctions, the approximate mileage, and the direction in which the calls are routed being indicated. It will be seen that all calls between exchanges except calls from Stoke to Trentham and from Newcastle to Chesterton are routed *via* Hanley.

In Fig. **3** are shown the routings of four typical calls. From case (*d*) it will be seen that a Trentham local call passes through Hanley and Stoke Exchanges and employs three junctions of an approximate length of 10 miles, five selector switches, and three repeaters. This type of connection is the most complicated to be met with in the Hanley Area and possibly anywhere outside London. The necessity for well-designed and efficient apparatus to avoid inferior transmission and distortion of dialled impulses can be appreciated.



HANLEY AUTO EXCHANGE AREA.

FIG. 2.

Switching selector repeaters are fitted at Burslem, Longton, Newcastle, and Stoke, those in the last three cases having drop back facility on the first digit, which enables these switches to function also as second selectors for local calls. The operation of this switch was fully described in the article on Leeds Telephone Area in the April, 1926, issue of this Journal, and it is unnecessary to give particulars here.

As the percentage of local traffic at Chesterton and Trentham is small, switching selector re-

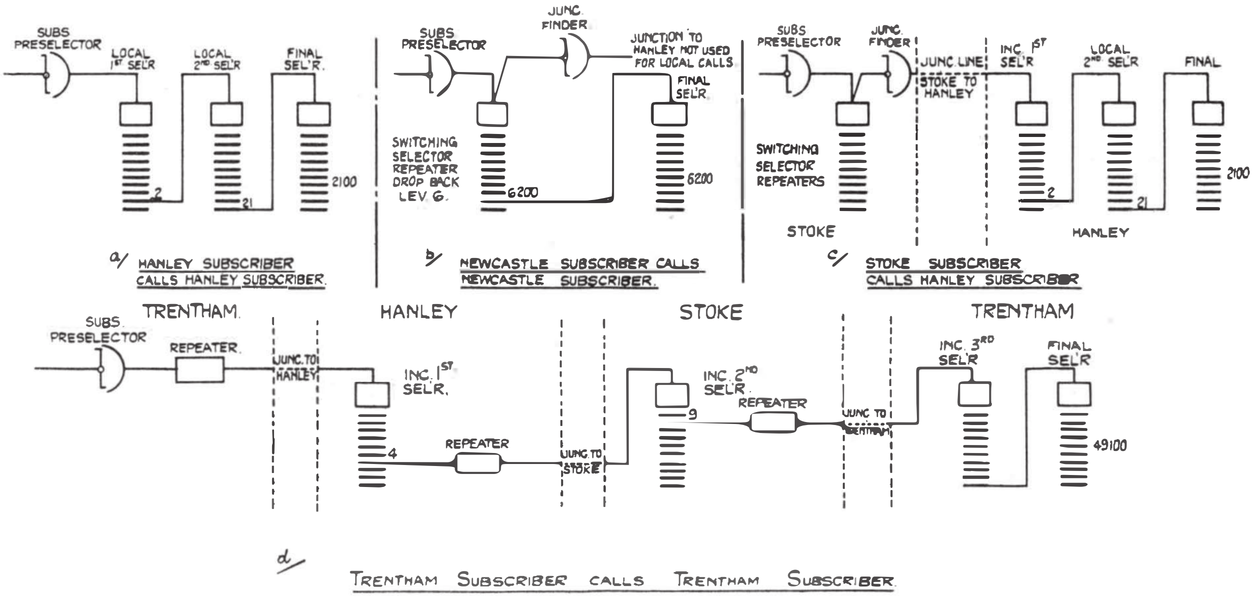


FIG. 3.—ROUTING OF TYPICAL CALLS.

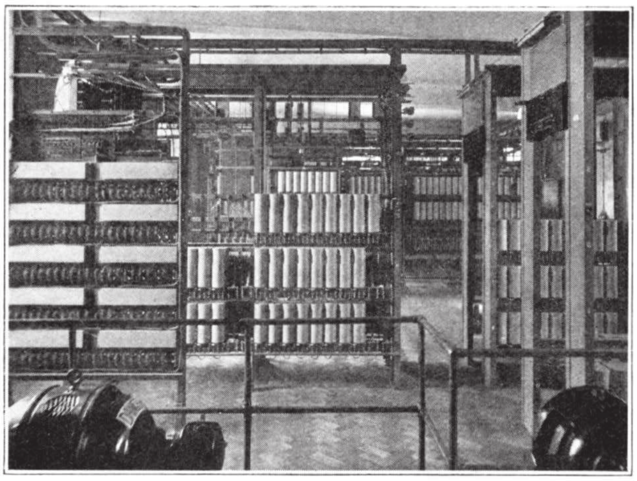


FIG. 4.—BURSLEM EXCHANGE.

peaters have not been provided and the first selectors for these exchanges are fitted at Hanley.

It may be mentioned that first selectors are also provided at Hanley for the Coin Box and Call Office lines on the Satellite exchanges in the Area.

Test Desks are provided at Burslem, Longton, Newcastle, and Stoke, while the testing at Chesterton and Trentham is done from the test desk at Hanley by means of the test distributors and test final selectors.

Arrangements have been made, as is now standard practice, for the extension to Hanley of the fault alarms at all the Satellites at such times as these are unattended; also for automatic start of the ringing machines at the Satellites, so that these machines only run while actually required.

Figs. 4, 5, and 6 are views in the apparatus rooms at Burslem and Stoke and show typical arrangements of equipment at such exchanges.

The manual switchroom is situated on the top floor of the Hanley building. The equipment is as follows:—

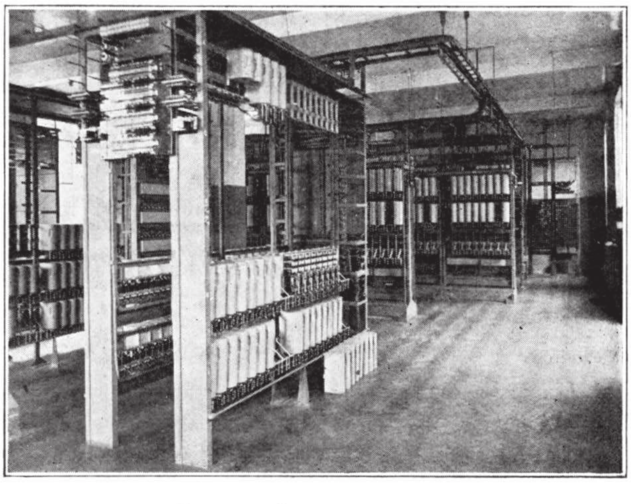


FIG. 5.—STOKE EXCHANGE.

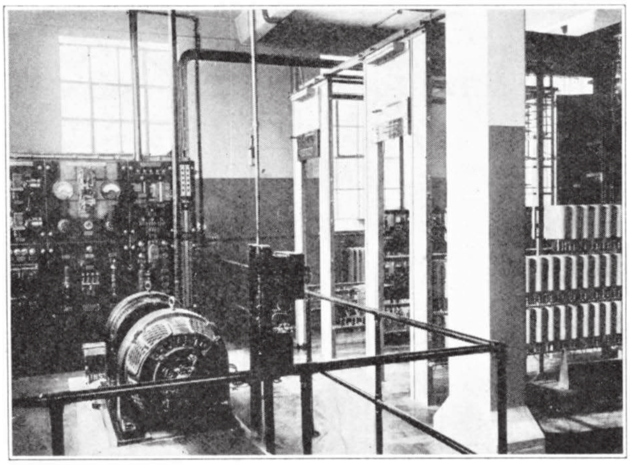


FIG. 6.—STOKE EXCHANGE. ANOTHER VIEW.

Manual Board consisting of
  1 Plug-ended Keysender Order Wire Junction position.
  3 Trunk Signalling positions.
  2 Jack ended Junction positions.
  13 " A " positions.
6 position monitors desk.
1 position supervisors desk.
1 position service observation desk.

On the keysender position are terminated busy groups of trunks from Liverpool and Manchester. For calls to automatic subscribers the telephonist, after assigning the junction, keys out the digits of the required number on a strip of 10 press keys numbered 1 to 0 fitted on the keyboard. At the finish of the call the connection is automatically cleared and all the switches released. For through calls the plug is used. When this is inserted into an outgoing junction jack a sleeve relay is operated which causes the automatic apparatus to be cut out, leaving the junction as an ordinary manual circuit. The clearing signal is received on a lamp associated with the plug. This method of dealing with through calls differs from the usual arrangement whereby such calls are transferred to another position by the operation of a transfer key.

Fig. 7 shows part of the front of the manual switchboard. The keysender position is at the extreme right-hand side. The strip of ten digit keys is the row nearest to the telephonist. At the top of the right-hand panel is the equipment to which the alarms at the various exchanges are extended when the Hanley apparatus room is unattended.

The service observation equipment provides facilities for observing service on 15 subscribers' lines at Hanley, 15 at Burslem, 10 at Longton and 10 at Stoke. One junction from each of these exchanges terminates on the Desk, and selective apparatus associates the junction in each case with the lines under observation.

This desk has been fitted temporarily in the switchroom, but will be removed to its permanent position after the old exchange equipment has been dismantled and the premises rearranged.

Thanks are due to Messrs. The General Electric Co. and Mr. J. S. Tebbitts, Sectional Engineer, Hanley, for photographs with which this article is illustrated.

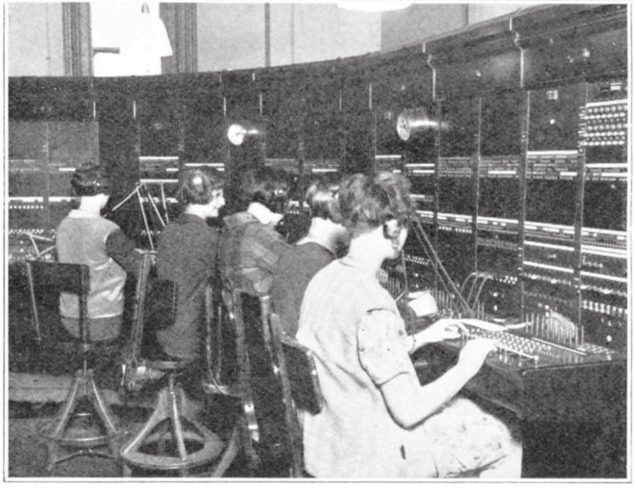


FIG. 7.—MANUAL SWITCHBOARD, HANLEY.

TIME SAVING TESTERS

FOR AUTOMATIC EXCHANGES.

By W. Prickett and H. S. Smith.

The Testing of Subscriber's Line Equipment (Homing Type Lineswitches).—The equipment individual to a subscriber's line circuit in an automatic exchange, as distinct from the remainder of the apparatus, which is common, is comparatively simple and consists of a lineswitch jumpered to the multiple banks, which are in turn cabled to the protector on the M.D.F. Simple as the equipment is individually, its numerical preponderance when considered collectively causes it to assume great importance when the question of testing-out a new exchange is under consideration. If, therefore, an undue proportion of the total testing time is not to be absorbed by lineswitch tests, it becomes necessary to deal with this equipment in a wholesale manner and it is to this end that Tester No. 58 has been developed.

The tester is arranged to cater for the tests required on a complete unit of one hundred line equipments and to perform most of the tests without further attention when once started. Access to each line is obtained by way of a spare multiple bank on which a special final selector is mounted. This selector forms part of the equipment of the tester and is arranged to connect testing circuits automatically to each line in turn. The access so provided caters for tests on each lineswitch and on each line circuit to the M.D.F. In addition, by making use of the normal final selectors mounted on the multiple banks, the wiring of the latter can be tested on every contact.

It will perhaps be of interest if details are given of the tests which are required for acceptance tests and a list is accordingly given below:

Line circuit to M.D.F.

Continuity, A & B wires	2	
Reversal	2	
Contact	2	
	6 per 100 ccts.	600

Bank Multiple.

Continuity, +, − and P wires	3	
Reversal	3	
Contact, P wire	1	
Wiper connection with bank contacts	3	
	10	
	per 16 banks 160 per 100 ccts.	16,000

Note: When P.B.X. units are concerned, this figure is increased by one third.

Lineswitch.

Operation, release and spring tension of line relay	3	
Operation, release and spring tension of C/O relay	3	
Continuity of +, − and P circuits	3	
Hunting and homing ...	24	
Wiper connection with outlets	72	
Continuity of outlet multiple	72	
Reversal of outlet multiple	72	
	249 per 100 ccts.	24,900

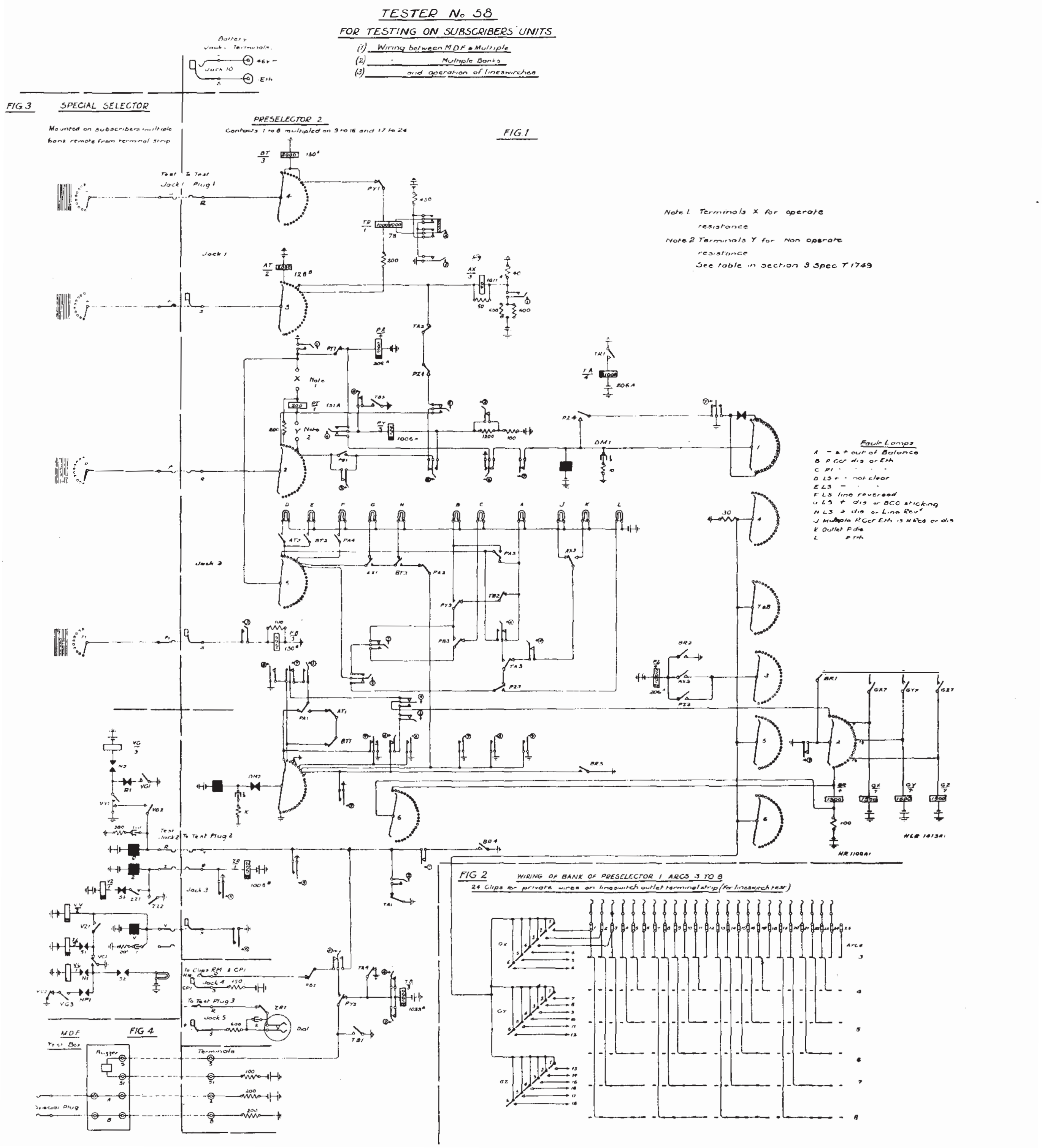
Outlets to Selectors.

Continuity of +, − and P wires	3	
Contact	3	
Acceptance and release of call	2	
	8 per 24 ccts.	192
	Total	41,692

The time taken to make the forty thousand or so tests with the aid of the tester is about three hours.

It is now proposed to give a brief description of the tester and to show its method of operation.

Tester No. 58.—The tester consists of a container in which two preselectors are associated with a number of relays and lamp signals. A special selector is also provided to enable connection to be made automatically to each of the


TESTER No 58
FOR TESTING ON SUBSCRIBERS UNITS
(1) Wiring between MDF & Multiple
(2) Multiple Banks
(3) and operation of lineswitches
Battery Jack Terminals
Jack 10
46v −
Eth
FIG 3
SPECIAL SELECTOR
Mounted on subscribers multiple bank remote from terminal strip
PRESELECTOR 2
Contacts 1 to 8 multipled on 9 to 16 and 17 to 24
FIG 1
Test Jack 1
To Test Plug 1
Jack 1
Jack 2
Jack 3
Note 1. Terminals X for operate resistance
Note 2 Terminals Y for Non operate resistance
See table in section 3 Spec T 1749
Fault Lamps
A − & + out of Balance
B P Ccr dis or Eth
C P1 " " "
D LS + " not clear
E LS − " "
F LS line reversed
G LS + dis or BCO sticking
H LS − dis or Line Revd
J Multiple P Ccr Eth is H Res or dis
K Outlet P dis
L " P Eth
To Test Plug 2
To Clips RM & CP1
Jack 4
To Test Plug 3
Jack 5
FIG 4
MDF
Test Box
Buzzer
Terminals
Special Plug
FIG 2
WIRING OF BANK OF PRESELECTOR 1 ARCS 3 TO 8
24 Clips for private wires on lineswitch outlet terminal strip (For lineswitch test)
GX
GY
GZ
Arcs

hundred subscribers' equipments on the unit under test. This selector is mounted on a spare multiple bank on the unit and is connected to the tester by means of plugs and cords. A terminal box containing a buzzer is used in addition during the test of the line wiring to the M.D.F.

The circuit arrangement of the tester is shown in the diagram. It should be mentioned that the release magnet of the selector only affects the rotary action. Vertical release is made by hand when required at the end of the test.

To enable the tests to be proceeded with, the tester is set up on a convenient support such as a portable cord repair table, adjacent to the unit under test on which the special selector is mounted, and connection is made to the exchange battery supply *via* the power jack fitted on each suite of units. Connection is also made to the P conductors of the outlet circuits on the unit terminal assembly by means of a set of twenty-four clips and cord provided for the purpose. The keys on the tester are then operated according to the test desired and cause the required conditions to be applied automatically to each line in turn. The tester ceases to work and displays an appropriate lamp signal when a fault is encountered.

The action which takes place is shown in the following extract from the " Notes on the Tester " which form part of the instructions supplied to exchanges where the tester is to be used.

(1) *M.D.F. Test.*—The M.D.F. test box, which contains the signalling buzzer, is connected to terminals S, S1, A and B and is located conveniently to the M.D.F.

Keys 1 and 4 are then operated and Preselector 2 in the tester is set to contacts 8 by depressing key 8. The special selector is set to contacts " 11 " by means of key 6.

The operation of key 1 energises the polarising coil of relay TR. TR operates and actuates relay TA at TR1 op. .

Key 4 completes the circuit from battery, *via* 100 spool, for relay PY, which together with relay PA operates to earth *via* PT1 nor. and key 1 op. . Relay PY disconnects the line testing circuit at PY1 op. .

Key 6 energises the vertical magnet of the special selector, which steps up to level 1, relay VV is operated in parallel with the vertical magnet and when the switch is stepped off normal, closes the circuit of relay VG at VV1 op. . Relay VG locks to earth *via* VG1 op. and the rotary interrupter springs R1. When key 6 is released, relay VV releases and the rotary magnet is energised *via* VG2 op. and VV1 nor. . The selector cuts-in to contact 1 on level 1, relay VG releasing when its locking circuit is broken at R1.

When the special selector wipers make connection with the line circuit connected to contacts " 11 " of the multiple bank, a circuit is completed for the lineswitch cut-off (BCO) relay *via* the P wire and wiper, contact 8 of arc 2 of Preselector 2, keys 3 and 2 nor., key 4 op., and relay PT to Earth at key 1 op. The BCO relay should now operate to provide a clear line circuit for the test to the MDF circuit and PT should operate to release relay PY. Should the P circuit be disconnected, relay PT will not operate, and lamp B will glow *via* PA3 op., key 4 op., TA3 op., PZ3 nor., key 2 nor., contact 8 of arc 5 and earth at key 1 op.

Connection is now made by means of a plug attached to the M.D.F. box, *via* the protector tags to each line of the 100 concerned in turn, but in bank order, *i.e.*, commencing with " 11 " and finishing with " 00 "

On each connection, momentary operation of the buzzer occurs if the line conditions are correct and the plug may then be moved to the next line.

The buzzer is operated as follows:—The application of the special plug to the line circuit on which the special selector wipers are resting, connects the 200 ohm spools A and B in the tester. Receipt of battery and earth of correct polarity and strength *via* the A and B lines to the unit, + and − wires to the bank, + and − wipers of the special selector, contacts 8 of arcs 3 and 4 of tester preselector 2 and PY1 nor. by relay TR, causes the latter to balance and release. Relay TA then releases also and operates relay TB at TA4 nor. Relay TB locks to earth at TB1 *via* PY2 nor. and key 4 op., actuates the M.D.F. buzzer and operates relay PY at TB3 op. Relay PY operating energises the rotary magnet of the special selector *via* key 4 op., PY2 op. and TB1 op. Relay TB releases when its locking circuit is broken at PY2 op. and the buzzer circuit is interrupted at TB1 nor.

Failure of TR to release, provided PT has operated, is due to a line fault and is indicated by lamp A which glows *via* PA3 nor., etc.

When the ten lines on level 1 have been tested O.K., the rotary action steps the special selector wipers off the bank and actuates the cam springs. The circuit of relay ZZ is now completed *via* S1 op. and VC1 nor. to earth. ZZ, operating, completes the release magnet circuit at ZZ2 op., releasing the selector shaft for rotary action only. Relay VZ is also operated at ZZ1 op., but being slow to operate allows the release to be completed before actuating the vertical magnet and relay VV by earth from VC1 nor. at VZ1 op. The shaft is now stepped up to level 2; relay VG is operated *via* N2 op. and VV1 op. and locks to earth at VG1 op. When VZ releases, the vertical magnet also releases, followed by relay VV. The rotary magnet circuit is now completed at VG2 op. *via* VV1 nor., and the wipers are cut-in to contacts " 21." Relay VG releases when its circuit is broken by the interrupter springs R1. The tests then proceed as for level 1 until level 0 is reached, when relay VC operates *via* the normal post contacts NP1, VG3 op. and VV2 nor. to earth and locks *via* N1 and VC1 op. On the completion of the tests on level " 0," the wipers are stepped off the bank as before, but as the circuit for relay ZZ is now broken at VC1 op. no further movement takes place. The special selector supervisory lamp glows, however, to indicate the conclusion of the test.

Keys 1 and 4 are now released.

It should be specially noted at this stage that, as after each line has been tested, the corresponding lineswitch makes a half revolution on the removal of the test plug from the protector tags, the wipers are now in the correct alternative position in readiness for completing the " clear line " test in Test 3. Care should be taken, therefore, to ensure that if any lineswitch on the unit under test is accidentally moved off normal, with the consequence that another half revolution is made when the wipers return home, it should be again operated to reset the wipers to the required position.

Release of Special Selector.—To release the special selector in readiness for the next set of tests, key 5 is first operated to actuate the rotary release, then the vertical dog is released by hand. This allows the shaft to fall back to normal. (Should it be necessary during the progress of the tests to retest any contacts, the selector may be reset to the beginning of the level concerned by the depression of keys 5 and 9 in turn).

(2) *Multiple Bank Test.*—Keys 1 and 2 are operated and test plug 3 is inserted in the test jack of the first final selector on the unit. Clip " RM " is also connected to the rotary magnet of this selector, the " G " relay of which should be wedged to prevent operation.

> *Note.*—This selector is referred to as the " Selector under test." It should be understood, however, that the test is being made on the bank and that the selector is only being utilised for this purpose. Separate instructions are issued for the final selector tests.

Key 8 should be depressed in order to ensure that tester preselector 2 is on contacts 8, and key 6 to set the special selector to contacts " 11."

A circuit is now completed from battery, 100 and 1200 ohm spools, relay PY to Earth at Key 2 op.

Relay PY operates to disconnect relay TR at PY1 op.

The digits " 11 " should now be dialled to step the final selector under test to a position on the first bank corresponding to that occupied by the wipers of the special switch.

The selector under test now operates in a normal manner and applies Earth to the " P " wire *via* the 125 ohm winding of relay H. Relay H is operated by the battery from the lineswitch cut-off (BCO) relay, and, locking, applies a full Earth to the P wire. This earth short-circuits tester relay PY, and the latter releasing completes the loop circuit for the − and + lines *via* relay TR. The operation of relay H applied ringing current to this loop circuit, and the completion of the circuit *via* relay TR causes the selector relay F to trip and connect relay D to the line circuit.

If the current now received from the latter be of correct polarity and strength, relay TR releases and disconnects TA at TR1 nor.

Relay TA, releasing, completes circuits:—

(1) From earth, TA4 nor. and key 2 op. for Relay TB, which operates and locks to earth *via* PY2 nor. and TB1 op.

(2) From earth, TA1 nor., key 2 op., to the rotary magnet of the special selector. The latter rotates to contacts 2 on the

bank and so removes the *s/c* from PY, which re-operates.

(3) From earth, TB1 op., PY2 op., PB2 nor., to the rotary magnet of the selector under test which also rotates to the next contacts.

Failure on the line or private circuits is denoted by a continuous glow on lamp A or B, *via* contacts PY3 nor. and TB2 nor., or PY3 op. respectively.

If the wiring between the contacts now connected be O.K., relays PY, TR and TA, which operated in the interval during which the wipers were rotating, again release. In this way both switches continue to rotate until contact 0 has been tested, when the wipers of the special selector will be stepped off the bank.

Relay ZZ now operates as before and causes:

(1) the special switch to rotate back, step up and cut-in to contacts "21" and

(2) relay ZR to operate to release the switch under test at ZR1 op.

The sequence of operations is repeated on levels 2 to 0, by dialling in turn digits "21" "31" and so on to "01."

When the whole of the 100 sets of contacts has been tested O.K., the special selector does not release but remains on level "0," with its wipers off the bank and supervisory lamp glowing, indicating the conclusion of the test on the first bank.

The special selector should now be released as before, the connections transferred in turn to each of the final selectors on the unit and the test repeated on each of the banks so equipped.

The spare banks may be covered by mounting a spare switch thereon for the duration of the test.

P.B.X. Units.—When the banks to be tested are of the P.B.X. type, key 3 should also be thrown in addition to keys 1 and 2, and clip CP1 should be attached to the P1 wiper tag on the wiper cord connection block of the selector under test. The effect of key 3 is to make the operation of the P wire testing circuit dependent on contact PB1, controlled by relay PB, which is operated by current received from battery *via* 150 spool, clip CP1 and the P1 bank wire.

Failure on the P1 circuit is indicated by lamp C, which glows *via* PB3 nor.

(3) *Line Switch Test.*—The 24 clips provided for making connection to the outlet P wires should be connected in order to the wiring on the tags of the line switch bank multiple terminal strip.

The tester preselectors should now be set to contacts No. 1 by operating key 7 and the special selector to contacts "11" by operating key 6.

Key 1 should also be depressed to operate relay TR. Relay TR operates in turn relay TA at TR1 op.

A circuit is now completed from earth, key 1 op., relay PT, contact 1 and wiper 2 of preselector 2, P wiper of special selector, bank wiring, jumper, BCO relay K and DM of line switch under test to battery.

The BCO should operate in series with relay PT and the "operate" resistance "X" and disconnect the line switch line relay and earth from the − and + lines. Relay PT releases PA at PT1 op., completing a circuit to earth for DM2 *via* wiper 1, contact 1, PA1 nor., key 1 op., key 7 nor., key 9 nor., wiper 2 of preselector 1 and key 7 nor. to E.

Preselector 2 steps to contacts 2 and relay PT, releasing, re-operates PA. Relays BT and AT are now brought into circuit, but will only operate if the line relay or earth have *not* been disconnected by the BCO. If either BT or AT operate, the circuit for DM2 is interrupted at BT1 op. or AT1 op., lamp D and/or E glows *via* AT2 op. or BT2 op., and no further rotation takes place, but if the + and − lines are now clear, preselector 2 rotates to contacts 6 and the BCO is released.

Relay PT is now connected *via* the additional "non-operate" resistance "Y" to the BCO, which should not operate at this figure. Relay PT, however, operates, releasing relay PA to complete the circuit of DM2 *via* contact 6 of arc 1, key 7 nor., PA1 nor., key 1 op., key 7 nor. and key 9 nor. to earth *via* wiper 2 and key 7 nor. Preselector 2 steps to contacts 7, *via* which relays BT and AX are connected to the − and + lines in order to test for correct calling conditions. If these relays operate satisfactorily, earth is applied to DM2 *via* PA2 nor., BT3 op., AX1 op., contact 7 of arc 5, wiper 5 and key 1 op. and preselector 2 rotates to contacts 8. If, however, one or both do not operate, lamp G or H glows *via* AX1 nor. or AX1 op. and BT3 nor. respectively, to indicate a line switch fault.

A 1200 ohm loop is now applied to the + and − lines *via* relay TR and PY1 nor., to operate the line switch. The line switch should now rotate to its first outlet and should switch through to the selector connected thereon. The selector, operating in turn, should earth the P wire to which connection is made by No. 1 clip on the terminal strip.

If a current of correct polarity and strength be received from the selector A relay by relay TR, the latter releases and breaks the circuit of TA at TR1 nor. Lamp A glows to indicate a failure in these conditions.

A circuit is now completed from Battery, *via* 300 ohms (two 600 spools), key 1 op., relay AX, TA2 nor., PZ1 nor., key 4 nor., key 2 nor., key 3 nor., contact 8 of arc 2 and wiper 2 to the multiple P wire.

If the latter has been correctly " busied " by the selector, relay AX, which operates only to an earth of low resistance, completes the circuit of relay PZ from battery, AX2 op., wiper 3 and contact 1 of arc 3 of preselector 1, clip 1 and P wire to the first choice selector earth.

Lamp J indicates a failure of this condition or an earth of too high a resistance.

Relay PZ now operates and :—

(1) Locks *via* its own contact PZ2 op. to the " busy " earth.

(2) Completes the circuits of DM1 and relay PY at PZ4 op.

(3) Disconnects lamp K at PZ3 op.

(4) Disconnects relay AX at PZ1 op.

Relay PY, operating, breaks the calling loop *via* relay TR at PY1 op.

The selector on outlet 1 should now release and remove the earth from the private, causing relay PZ to release and the line switch to rotate " home."

DM1 being disconnected at PZ4 nor., now de-energises and steps preselector 1 to contacts 2.

An earth fault on the private circuit is indicated by relay PZ failing to release and by lamp L glowing. If this earth be of low resistance the line switch will also skip the outlet concerned. This fault may be caused by a faulty selector " B " relay.

Lamp K indicates that the line switch has not made connection to the correct outlet or that the clip has become detached.

The P wire of the first outlet is now " busied " against further use by an earth of 30 ohms resistance applied from wiper 8 of preselector 1 to contact 2 of arc 8 and so to clip 1.

Relay PY also releasing, re-connects the loop *via* relay TR to the + and − lines at PY1 nor.

The line switch again operates and as outlet 1 is now engaged should rotate its wipers to the second choice, the P wire of which should be duly made " busy " when the selector is seized.

Relays PZ and PY are again operated as before, causing the earth on the P wire of the first outlet to be maintained *via* contact 3 of arc 8. Earth is applied to the P wire of the second outlet *via* contact 3 of arc 7.

The sequence of tests continues until each of the 24 outlets has been tested, the application of the busy earth to each of the first three sets of six being taken over in turn by the locking relays GX, GY and GZ, which are actuated by preselector wiper 2 in passing contacts 7, 13 and 19 on the completion of the tests on outlets 6, 12 and 18 respectively.

When the 24th outlet has been tested O.K., preselector 1 steps to contacts 25 and circuits are completed for :—

(1) Reliay BR *via* wiper 2. BR operates and releases relays GX, GY and GZ at BR1 op. All outlets are now disengaged.

(2) The rotary magnet of the special selector *via* key 7 nor. and BR4 op. The selector steps forward and connects the test circuit *via* its wipers to the next subscriber's line in the multiple.

(3) Relay PZ *via* BR2 op. PZ energises DM1 *via* PZ4 op. and key 7 nor.

(4) DM2 *via* interrupter springs, wiper 1, contact 8 and BR3 op. Preselector 2 rotates to contact 9, where the multiple of contacts 1 to 8 recommences and short circuits relay BR at contact 1 of arc 6. Relays BR and PZ now release and preselector 1 rotates to contacts 1 in readiness for recommencing the series of tests.

The sequence of operations is repeated for each of the jumpered lines in the 100.

In the case of unjumpered lines (usually 46-49 and 95-99) to which no line switch is connected, it is necessary to rotate the special switch to the next jumpered circuit. This is effected by operating key 9 the appropriate number of times (generally 5), allowing an interval between each operation to enable the tester to perform a partial test.

When the whole of the 100 lines on the unit have been tested, the special selector will come to rest with its wipers off the bank and the supervisory lamp glowing.

FAULT INDICATING LAMPS.

Lamp.	Test.	Fault indicated.
A	1, 2 & 3	Line circuit out of balance, *i.e.*, Reversed, dis., contact, etc. In Test 1 may be due to cut-off relay failing to operate.
B	1 & 2	Private circuit dis. or earthing.
C	2	P1 circuit dis. or earthing.
D	3	Lineswitch + line not cleared by operation of cut-off relay.
E	3	Lineswitch − line not cleared by operation of cut-off relay.
F	3	Lineswitch line circuit reversed.
G	3	Lineswitch + line dis. or cut-off relay sticking or contact faulty.

FAULT INDICATING LAMPS—(*continued*).

Lamp.	Test.	Fault indicated.
H	3	Lineswitch − line dis. or cut-off relay sticking or line circuit reversed.
J	3	Multiple P circuit busy earth is high resistance or dis.
K	3	Outlet P circuit dis. or lineswitch has overstepped.
L	3	Outlet P circuit earthing.

RESISTANCE TABLE.

Exchange.	46 V Test.	Scheme.				
		C	E	H	S	W
Director.	Operate.	200		200		100
	Non-operate.	600		600		1400
Non-Director.	Operate.	0		0		0
	Non-operate.	450		450		800

NOTES ON THE EFFECTS OF HUMIDITY ON C.B. TRANSMITTERS.

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THE peculiar behaviour of carbon granular transmitters used in C.B. systems in tropical countries, where warm humid conditions exist, has long been one of the special problems before the telephone engineer in these countries. In the East, and in the far East, some telephone administrations have followed continental practice in favouring a telephone of the hand combination type, which has certain advantages, and now appears to be returning to favour in other countries. The transmitters used with these sets are usually of the inset type, carbon diaphragm, but a solid back type of inset has also been used. The difficulties met with arise from the fact that transmitters of different types which appear to be quite satisfactory under European conditions are in many cases unable to stand up to the extremes of heat and humidity met with in the tropics without change.

In all cases the failure is due to the fact that in those tropical countries which enjoy a rainy season, the humidity reaches an extraordinarily high figure, and during those seasons, unsuitable transmitters show a large increase in resistance (often 100%) and an inabiliy to carry their normal working current, which may develop into "frying," rendering the transmitter useless. It is well established that the effect is due to humidity, for, in the particular case under the writer's notice, the year is divided into two well defined seasons: a dry season with very low humidity (minimum indoors about 30—40%) from November to May, followed by a rainy season, during the remaining months, when the humidity reaches 80 to 90%. The manner in which the humidity varies is shown in the graphs which are from records taken by the Meteorological Dept., Government of India. The figures differ from the ordinary published records, which are taken in the open air. The latter show much larger differences. The figures of the graphs represent the humidity in an average ventilated building, being the conditions under which a telephone usually operates. The reason for this is, of course, that the heat absorption of a building tends to flatten out humidity variations, by the lag in temperature variation as compared with the open air, in which the diurnal temperature variations may be very large. Each point on the graph is the average of seven days reading, eliminating daily variations, which are also considerable. It was found by experience that the 10 a.m. reading is the average daily humidity in an ordinary building.

The first fact which emerged was that the type of inset standard in Europe behaved normally during the months of low or moderate humidity, but became abnormal as soon as the humidity became excessive, returning to normal with the return of drier conditions. This variation was undoubtedly present formerly in the L.B. transmitters used on the old magneto system, but did not lead to trouble because the L.B. transmitters were used in a circuit where an increase of transmitter resistance would at once produce a decrease of transmitter current, since the transmitter resistance was the only important resistance in circuit; whereas under C.B. conditions a relatively large increase in transmitter resistance has but little effect in decreasing the current which the transmitter is calld upon to carry. What follows applies to C.B. systems.

When it has become clear that the presence of damp in the transmitter was the origin of the trouble, a number of attempts were made to produce a sealed damp proof inset. Although these insets were proved to be damp proof in the sense that they could be put under water without ill effect, they showed no improvement over the original insets, which were not waterproof, when put into use during the season of high humidity. This made it obvious that the transmitters were not being affected by moisture in liquid form condensed from the air outside the inset, but by water vapour in its true gaseous state penetrating to the granules and thereafter condensing to liquid form. As points are favourable to condensation, the carbon granules lend themselves admirably for the purpose and the result is a reduction in their current carrying capacity.

On consideration, it is clear that an inset sealed under conditions of normal humidity in the factory, and afterwards used under conditions of much higher temperature and humidity, is then subject to internal pressure, and unless it is truly gas-tight and not merely water- proof, the damp air will eventually mix with that inside and thereafter condense, since a small drop in temperature will cause considerable condensation when the humidity is approaching saturation for that particular temperature. So far, attempts to produce a gas- tight inset have not succeeded, but manufacturers interested have the problem in hand.

In order to obtain further information two batches of 13 different types of transmitters were put under daily observation and test over a period of about 18 months. Each transmitter was tested daily in a suitable telephone on the cord circuit for which it was designed. Tests were made for transmission against a standard W.E. type set, on the standard cord circuit with 300 ohm local line, followed by a measurement of transmitter resistance. At the same time, some hundreds of resistance tests were made on transmitters after actual use.

Since there seemed to be no means of excluding the damp air, an attempt was made to arrive at a solution from a fresh angle, suggested by the observation that whereas some transmitters, notably those of a low resistance relative to the cord circuit current supply resistance used, never became very much higher in resistance, and afterwards in drier weather returned to normal resistance; others (and here notably those of high normal resistance) showed 100% increase in resistance, became noisy, and remained permanently high resistance, even after the damp conditions had disappeared. These were, in fact, burnt out. As examples, one type of inset supplied to operate on a Stone circuit, 24 volt, with relay-retard feed 400^{ω} + 400^{ω} ohms, maximum transmitter current about 20 m.a., had a nominal resistance of 400 ohms which became, in the humid season, 600 to 800 ohms in many cases, with frying and permanent injury to the transmitter. Similarly, a solid back transmitter of standard size, adapted for use on an H.M.T. set, operating on a standard W.E. type cord circuit, had a nominal resistance of 150 ohms, which increased to 300 to 400 ohms in many cases, again with frying and pitting of the polished electrodes. Here an improvement was obtained by using a smaller size of carbon granule, and making up the cells to a lower resistance. Different transmitters were affected in the same manner, with differences in degree; transmitters on short lines were most affected, and the trouble could be reduced by reducing the current supply to the transmitter.

Bearing this in mind, we may regard a transmitter, for present purposes, merely as a fixed resistance required to carry a certain current, depending on the cord circuit with which it is to be used, and consider what variations may be expected with change in humidity and change in design of the transmitter. We may regard a transmitter as consisting of a resistance made up of r rows of granules, in each row n granules. In any one row there will be $n + 1$ contacts, including those between the end granules and the front and back electrodes. Call the average contact resistance between granules (or granule and electrode) x, and the average internal resistance of a granule y; then the resistance of any one row is

$$ny + (n + 1)x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

and the resitance of the whole transmitter is

$$\frac{ny + (n + 1)x}{r} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

But if the transmitter is not " packed " and is ordinarily efficient then $(n + 1)x$ must be large compared with ny since it is on the variation of $(n + 1)x$ that the transmitter operates. We may say then that the transmitter resistance is approximately

$$R = \frac{(n + 1)x}{r} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Suppose now that the condensation at points on the granules is the cause of increase of contact resistance from x to $x + dx$. Then the transmitter resistance becomes

$$\frac{(n + 1)(x + dx)}{r} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

and the increase of resistance due to damp is

$$\frac{(n + 1)x}{r}$$

which is proportional to the dry resistance $\dfrac{(n + 1)dx}{r}$

It follows from this, if there are no secondary effects, that the transmitter may be expected to increase in resistance by an amount which will be proportional to its initial resistance, and therefore a high initial resistance is to be avoided, This agrees very well with observed results. There are, however, secondary effects. The above is the ideal case where all rows are affected equally. Actually it will happen that in some rows the increase in contact resistance will be much more than in others. In such a case the high resistance rows cease to be effective as current carriers, and as the current to be carried remains practically the same, the effective rows are called upon to carry an excess load which leads to burning in the effective rows, and these in turn become defective, and react on others. It appears then that there is a cycle of effects which becomes cumulative under bad conditions. Thus if a transmitter is badly designed, so that the current which it must normally carry is near its maximum current carrying capacity (without frying) and is operated later under warm humid conditions, we have the following effects: (1) the transmitter resistance is increased due to damp; (2) the current carrying capacity is reduced; the current flowing remaining nearly the same; (3) frying begins, reducing the number of current paths; (4) transmitter resistance is further increased; (5) the effect of (4) is now added to (1) and the cycle repeats until the transmitter becomes useless. There will be no building up to the point of frying if the cycle is broken at its third stage, and this will be the case if the transmitter under damp conditions and in spite of its damp-increased resistance can still carry the maximum current for which it is designed without burning.

In order to do this the transmitter must carry in a dry atmosphere a current at least 50% more than the maximum of the circuit on which it is to operate. In the case of hand combination sets the margin should be 100% to allow for the fact that they may be used in non-vertical positions. From the expression given for the total resistance there are several obvious ways in which the current carrying capacity of the transmitter could be increased. If the cross section of the cell is increased then r is, and also the current carrying capacity, but this can not be pushed too far. R may also be reduced by reducing n, *i.e.*, by reducing the distance between electrodes; but this does not improve the current carrying capacity of a row, which depends only on $x + dx$. The conditions are improved if the size of the granules is reduced. The effect of this on R should be nil, while r, the number of paths, is increased directly with benefit. The resistance of a single row is also increased directly, but this does not affect its current carrying capacity, which depends only on $x + dx$. The reduction in size of the granules cannot, of course, be carried too far since very small granules tend to pack.

This conclusion agrees very well with observed results in that the best results obtained so far have been with a type of inset using small granules, and the worst with another type using coarse granules. These results are brought out in the curves taken from the daily observations over eighteen months mentioned above. Curve No. 1 shows the results obtained on an inset which has proved satisfactory. It has a normal resistance of 100 ohms and is used on a C.B. system where the cord circuit is Stone type with relay-retard impedance 400 + 400 ohms and voltage 24 volts. The weekly average transmission value on 300 ohm loop and the weekly average transmitter resistance are shown against the weekly average relative humidity. The number of these sets under test was four and the number of observers two. Each point on the transmission curve represents the average of twenty-four measurements by two observers and may be taken as free from all accidental variations. Similarly, the transmitter resistance curve is the average of daily readings and is representative. The remarkable agreement between the variation in humidity and the variation in transmitter efficiency will be noticed. There is also a close agreement between the variation in transmitter resistance and humidity variation, with maximum resistance during the period of maximum humidity. It will be noticed that these insets rarely vary more than 25% above and below normal resistance, and that with the disappearance of abnormal humidity returned to normal or lower. This transmitter has been used to replace former types and continues to give satisfaction, as would be expected.

The second set of curves refer to a type of inset under trial which was not satisfactory, and represents the effects in a poorly designed transmitter, possibly satisfactory in Europe, under tropical conditions. These insets were designed to work on the standard W.E. type cord circuit, 22 volts, and the figures on which the curves are based were obtained as in the first case. These curves show that this transmitter was unstable under damp conditions, as may be seen from the abrupt variations in transmission value. These insets became noisy during the damp season and thereafter their transmission values are nominal. The transmitter resistance steadily increased during this period from normal (35 ohms in this case) until, during the weeks of maximum humidity, the resistance had become 100% more than normal. At this point the two principal causes of increased resistance began to react on one another and the resistance rapidly increased to an abnormal figure, at which the inset became defective and was no longer able to recover its normal value, even when the humidity again became low.

The results obtained from the remaining types of transmitters tested show effects which lie between the two extremes given, and confirm the general conclusion that special care is required in selecting a transmitter for tropical use, and that allowance must be made in the design of the cell, and in the type of granule used, to minimise the changes in resistance which are apparently inevitable.

It is interesting to note that the standard solid back pedestal sets used as references, themselves showed variation in resistance with change of humidity. The standard set (from necessity, on account of the high value of the current which it must carry on zero loop) is well able to carry the working current on ordinary subscribers' loops of say 100 ohms to 300 ohms on which the current is much less than maximum; and for this reason administrations in the East using this

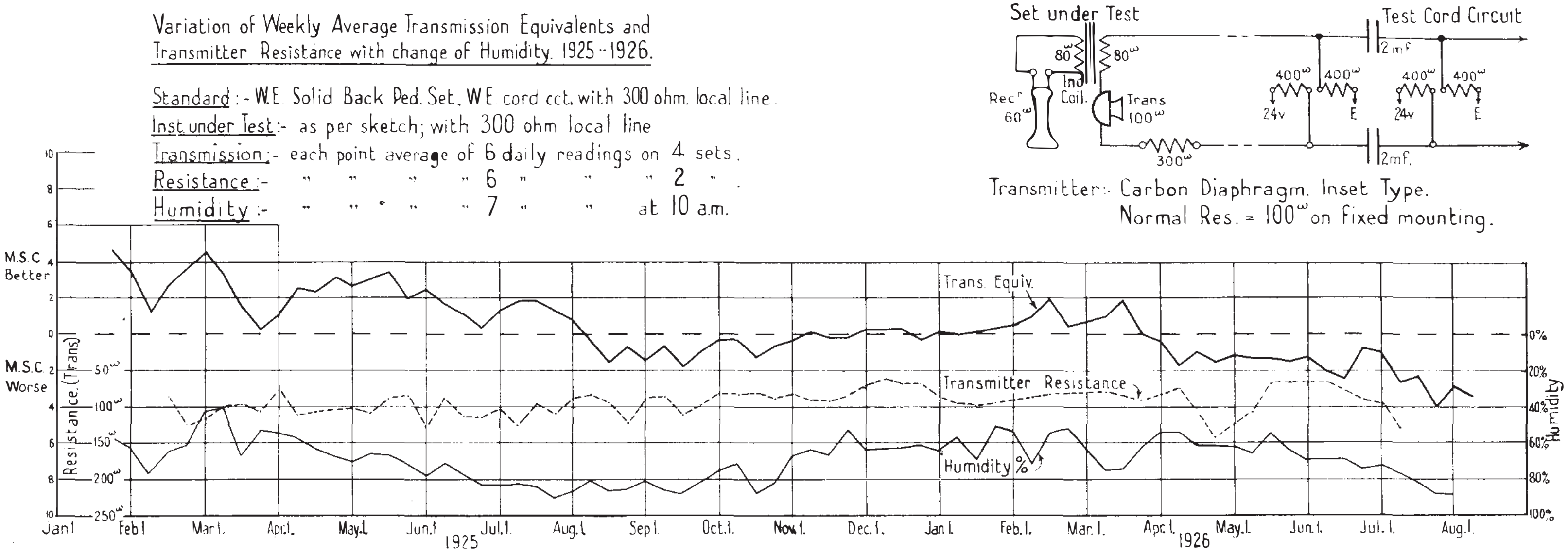

Variation of Weekly Average Transmission Equivalents and Transmitter Resistance with change of Humidity. 1925–1926.
Standard :- W.E. Solid Back Ped. Set. W.E. cord cct. with 300 ohm. local line.
Inst. under Test :- as per sketch; with 300 ohm local line
Transmission :- each point average of 6 daily readings on 4 sets.
Resistance :- " " " " 6 " " " 2 " .
Humidity :- " " " " 7 " " at 10 a.m.
Set under Test
Test Cord Circuit
80ω
80ω
Ind. Coil.
Recr 60ω
Trans 100ω
300ω
400ω
400ω
24v
E
2 mf
2mf.
Transmitter :- Carbon Diaphragm. Inset Type.
Normal Res. = 100ω on fixed mounting.
M.S.C. Better
M.S.C. Worse
10
8
6
4
2
0
2
4
6
8
10
Resistance (Trans)
50ω
100ω
150ω
200ω
250ω
Trans. Equiv.
Transmitter Resistance
Humidity %
0%
20%
40%
60%
80%
100%
Humidity
Jan.1
Feb.1
Mar.1.
Apr.1.
May.1.
Jun.1.
Jul.1.
Aug.1.
Sep.1.
Oct.1.
Nov.1.
Dec.1.
Jan.1.
Feb.1.
Mar.1.
Apr.1.
May.1.
Jun.1.
Jul.1.
Aug.1.
1925
1926

FIG. 1.

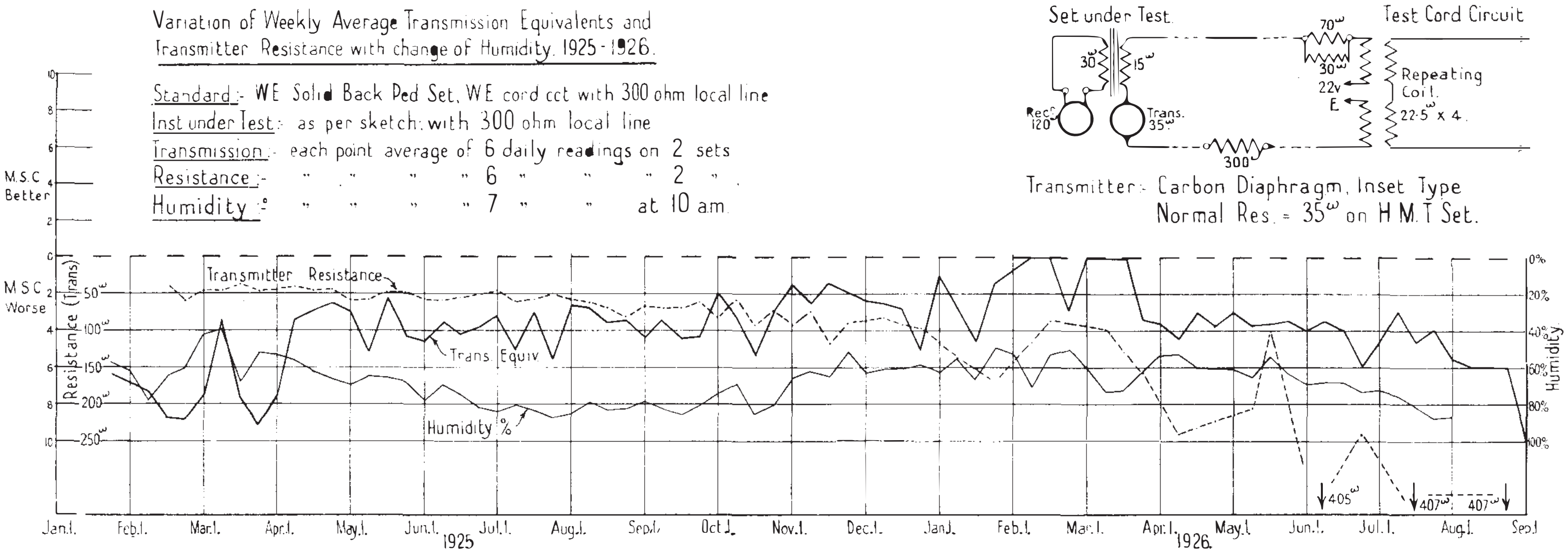

Variation of Weekly Average Transmission Equivalents and Transmitter Resistance with change of Humidity. 1925–1926.
Standard :- W.E. Solid Back Ped. Set. W.E. cord cct. with 300 ohm local line
Inst. under Test :- as per sketch; with 300 ohm local line
Transmission :- each point average of 6 daily readings on 2 sets
Resistance :- " " " " 6 " " " 2 " .
Humidity :- " " " " 7 " " at 10 am.
Set under Test.
Test Cord Circuit
30ω
15ω
Recr. 120
Trans. 35ω
300ω
70ω
30ω
22v
E
Repeating Coil.
22·5ω x 4.
Transmitter :- Carbon Diaphragm, Inset Type
Normal Res. = 35ω on H.M.T. Set.
M.S.C. Better
M.S.C. Worse
10
8
6
4
2
0
2
4
6
8
10
Resistance (Trans)
50ω
100ω
150ω
200ω
250ω
Transmitter Resistance
Trans. Equiv.
Humidity %
405ω
407ω
407ω
0%
20%
40%
60%
80%
100%
Humidity
Jan.1.
Feb.1.
Mar.1.
Apr.1.
May.1.
Jun.1.
Jul.1.
Aug.1.
Sep.1.
Oct.1.
Nov.1.
Dec.1.
Jan.1.
Feb.1.
Mar.1.
Apr.1.
May.1.
Jun.1.
Jul.1.
Aug.1.
Sep.1
1925
1926

FIG. 2.

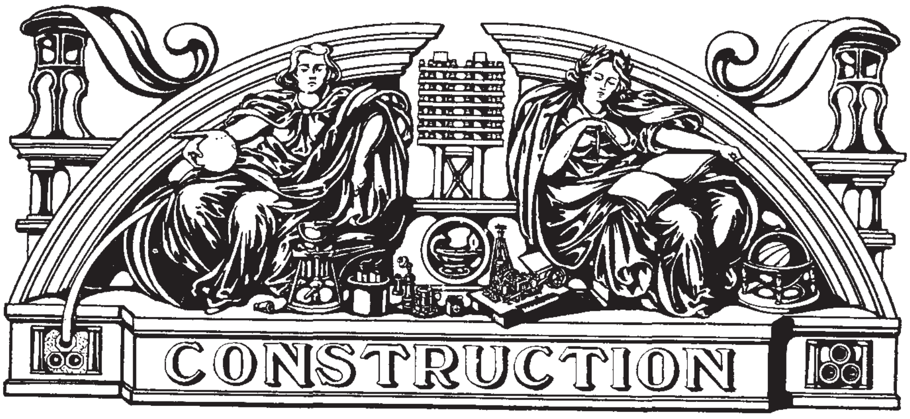
type of telephone have not experienced any general trouble. The standard solid back transmitter is, in fact, a good example of a type designed to carry its working current without burning even under severe conditions.

Nevertheless, one of the working standard telephones used as references developed frying between September 2 and 4, 1925; that is, during the period of maximum humidity. A permanent cure was effected by violently shaking the transmitter. Similar trouble is not uncommon with this type of set under these conditions on very short lines, *e.g.*, service lines within the exchange building where the transmitter current is nearly maximum. In spite of the apparent superiority of the solid back transmitter, it is quite unsuitable in its standard form on exchange systems such as that mentioned above, where the maximum current supply on zero loop is not more than 30 mA, on account of the high resistance of the current supply circuit, and it is for this reason that the high resistance inset is preferred, as well as for its superior articulation. In countries where the parties to a call are commonly conversing in a language or dialect which is foreign to one, or even both, the provision of a good grade articulation is of the greatest importance, and it is the writer's experience this gives the greatest general satisfaction even if the improvement is made at some expense in volume. A reference to this point, which has received little attention in countries of one language, will be found in part 3, Vol. 20, of the *I.P.O.E.E. Journal*, pages 208 and 213, as applied to long distance lines, but the remarks of Dr. Luschen apply with equal force to apparatus used on local calls in countries where the listener has not the association of familiar words and phrase to help in reception, and where the user is frequently without any developed telephone sense.

The fact that the standard of reference in the above tests was itself variable makes the transmission results purely relative, and the effect on the curves is to mask, in some unknown degree, the variations in efficiency with humidity, since there is no reason to suppose that the standards were exceptions to the general rule. Since completing the curves it has been found by comparison with calibrated working standard transmitters received from London that the transmitters used in these tests as standards were 3 m.s.c. worse than the accepted standard. This correction should be applied to the transmission equivalents, although the curves correctly illustrate the variations which it is intended to show.

The atmospheric conditions necessary to produce these effects on transmitters depend largely on temperature and its variations. Thus, during the dry season in Bengal the relative humidity in the open air commonly reaches 90% between sunset and sunrise, the cause being the large drop in temperature. Transmitters remain unaffected since there is no corresponding drop in temperature indoors on account of the heat stored in the buildings during the day. Similarly, relative humidity reaching 90% is not unknown in temperate climates during wet periods of low temperatures (winter months), but the effects here noted are not present because of the great difference between the humidity in the open air and in buildings, which results from the use of artificial heating and less ventilation. During the wet season in the tropics the temperature is not only high but remarkably constant, with little difference between night and day temperatures. During these months the temperature inside buildings is on the whole less than in the open air, and hence the humidity indoors tends to be higher. As the air is allowed to circulate with the utmost freedom, transmitters (and all telephone equipment for that matter) may be said to be fully exposed to outside atmospheric conditions; and it is under these conditions, maintained over a period of time, that transmitters may become defective. The time element is most important, and should be carefully considered in any test reproducing tropical conditions artificially.

In order to indicate more graphically to the home reader the effects of high temperature and humidity it may be added that a relative humidity of 85% with a temperature of 80 to 90 degrees F. produces fungus in one's clothes and shoes in 24 hours, expands key spring assemblies sufficiently to break the clamping screws if the insulating material is at all hygroscopic, and makes the maintenance of insulation of exchange equipment a matter of the greatest difficulty.



SOME ECONOMIES IN CONCRETE.

[We propose in this volume to devote some space to the external constructional side of the Department's activities and to begin with we have pleasure in publishing extracts from a pamphlet bearing the above title, issued by the long-established firm Messrs. G. and T. Earle (1925), Ltd., Hull, and compiled by their Chief Chemist, Mr. J. E. Worsdale, A.R.C.S., B.Sc., A.I.C., A.M.I.Struct.E. The contents of the pamphlet are followed by a laboratory report upon the chemical processes that operate during the setting of cement. It is not claimed that the report is complete and conclusive; the mechanism of the setting and hardening of cement is a matter about which a considerable divergence of opinion exists, even among experts. It will serve, however, to give our readers, who have not the time to make an intensive study of the subject, some indication of what is thought to be happening during the critical period just after the concrete has been mixed and laid.—EDS., *P.O.E.E. Journal.*]

Making of Concrete.—Concrete is made up of three constituents, aggregate, cement and water, of which the aggregate can be divided again into coarse and fine. These separate constituents are all essential to concrete, and the good quality and proper use of each reflects itself in the quality of the finished concrete, whilst on the other hand the unsuitability or misuse of any one of them can result in poor concrete.

Each of the materials will be dealt with separately in an attempt to show how a study of these can be made to improve the quality of concrete and also to lessen the cost.

Coarse Aggregate.—Coarse aggregate usually consists of gravel, broken brick or broken stone. It should be hard and have no tendency to split, like, for example, shale.

The strength of concrete is largely dependent upon the strength of its aggregate, and if the aggregate is weak it limits the strength of the concrete made from it. The size of the aggregate is of great importance in relation to the use of the concrete, since very large aggregate cannot be used with complicated reinforcement, or to produce thin concrete sections. The aggregate should particularly, not be of a uniform size, but should be well graded in the size of the particles, which should vary evenly from the largest to the smallest. This grading has a very great influence upon the strength and watertightness of the concrete and also upon its cost. At this point it will be of interest to show to what a large extent the grading of an aggregate can influence the cost per cubic yard of concrete. It is, of course, well-known that to produce one cubic yard of concrete, considerably more than a cubic yard of dry materials are required, but it is probably not generally known what a great influence the grading of the aggregate has upon these quantities. If the aggregate is composed of evenly sized particles, a given volume will shrink on being made into concrete very much more than if the aggregate had been graded. The following practical test will illustrate this point:

Aggregate A consists of ⅜ in. chips of even size.

Aggregate B consists of ⅜ in. chips down.

In making concrete the proportions 4 : 2 : 1 by volume were employed and the same sand was used in each case.

QUANTITIES IN CUBIC YARDS TO MAKE 1 CUBIC YARD OF CONCRETE.

	Aggregate.	Sand.	Cement.	Total.
Aggregate A...	.96	.48	.24	1.67
Cost	13/3½	6/7½	16/9½	36/8½
Aggregate B ...	.82	.42	.21	1.45
Cost	12/7½	5/11	14/8½	33/2½

Below the figures for quantities, are put the prices of these quantities at the following rates :

Aggregate and Sand, 14/6¼ per ton.

Cement, 72/7 per ton.

It is seen that when aggregate A (ungraded) is used, 1.67 cubic yards of dry material are required to produce 1 cubic yard of finished concrete, but when aggregate B (graded) is used, only 1.45 cubic yards are required and a saving in price of materials alone, of 3/5d. per cubic yard of concrete is shown.

The foregoing results of actual tests are extracted from a paper by Mr. B. Price Davies, published in the *Structural Engineer,* and give a practical demonstration of how a thorough understanding of concrete materials can save money.

Fine Aggregate.—This usually consists of sand or crushed stone screenings, the particles of which should be graded in size as in the case of coarse aggregate. It is preferable for the dust to be present only in minute quantities, and for the main bulk of the material to be coarser than will pass a 50 mesh sieve. The presence of fine dust has a very considerable weakening influence upon concrete and the good effects of the removal of this material from fine aggregate may very considerably repay the cost of washing, and when comparing two materials for suitability, the amount of fine dust or dirt should never be neglected. Sand often contains organic matter, which has a very harmful action upon the cement, and a way of testing for this is to shake up some of the sand with a dilute solution of Caustic Soda, and noting the colour produced.

If sand is shaken with an equal volume of 3% solution, and the colour of the liquid, after 24 hours standing, is no darker than amber, the sand may be considered satisfactorily free from organic matter.

Aggregate in General.—There are certain substances used as concrete aggregate which are quite unsuitable by reason of their chemical composition, of which a noteworthy instance is that of some qualities of Blast Furnace Slag. This material often contains sulphur compounds, and these have a very harmful, disintegrating action upon cement. The bad effects of sulphur compounds, however, are not immediate, and some months or ever years may pass before the disintegration becomes apparent.

If the slag is comparatively free from sulphur, it can produce excellent concrete, but the absence of sulphur cannot be guaranteed, and before any batch is used, a chemical test should be applied.

Certain types of Spar and Chert also need careful chemical examination before use, since, if the Spar comes from zinc bearing rocks, there is the likelihood of the impurities in the Spar rendering the concrete very slow setting. Our experience of this type of aggregate has shown that the danger is that the concrete should dry out before the set has taken place, but if the concrete is kept wet, it will ultimately set and harden satisfactorily. We have had a number of experiences of this nature, and we would advise that small pats be made of the aggregate and cement and examined carefully to see that they harden satisfactorily. When considering the use of a fresh supply of aggregate of which one has had no previous experience, the small trouble entailed will always be repaid by the knowledge that the materials are satisfactory ; or if the tests should show the material to be unsuitable, considerable sums of money may be saved.

Cement.—It is, of course, the cement which gives concrete its strength, and it follows that the stronger the cement, the stronger will be the concrete. The British Standard Specification calls for cement to have a certain strength, and the adoption of this specification has done an immense amount of good in raising the quality of Portland Cement to a reasonable level. Now when certain proportions for the concrete are specified on a job, unless a particular brand of cement is also specified, B.S.S. cement is meant.

If a cement on testing, exhibits, say, double the strength of B.S.S. requirements, surely a leaner mix using this cement will produce concrete of equal strength.

The extent to which economical mixes can be obtained by the use of a high class cement is illustrated by the following schedule of tests of 6″ concrete cubes at 28 days, expressed in lbs. per sq. inch. The conditions of preparing and storing the cubes prior to testing were the same in each case.

Cement.	Concrete Proportions.				
	6 : 1	7 : 1	8 : 1	9 : 1	10 : 1
Sample A ...	4850	3780	2690	2130	1900
Sample B ...	2050	—	—	—	—
Sample C ...	2290	—	—	—	—

It will be seen that concrete made 6 to 1 with sample " B," has less strength than that made 9 to 1 with sample " A " and 6 to 1 with sample " C " is weaker than 8 to 1 with sample " A."

All three cements are above the requirements of the British Standard Specification of 325 lbs. per sq. inch, for the 3 to 1 sand and cement mixture tested at the age of 7 days, as shown below:—

Cement.	Lbs. per sq. inch.
Sample A	615
Sample B	350
Sample C	370

High testing cement is manufactured by choosing the proper raw materials and carrying out each process of the manufacture very thoroughly. One of these processes is the grinding of the clinker to cement, and thoroughness in this part of the manufacture produces a very finely ground cement. Now for a given weight, a finely ground cement will occupy a greater bulk than one coarsely ground, and since it is usually proportioned by volume, a distinct saving is brought about. The difference in bulk is often as much as 5%, which represents a saving of 1/- in the £. Moreover, the coarse material which does not pass through a 180 mesh sieve has practically no cementitious properties, and is of as much value as so much sand; the buying of cement residue is therefore a very dear way of buying sand. A finely ground cement is thus shown to be a better cement and a cheaper cement in use.

Water.—We now come to the last constituents of concrete, viz.: water. This, however, is by no means the least important, since a wrong use of water can effectively negative the good properties of aggregate and cement. It is a fact, now probably undisputed, that excess of water in concrete reduces its strength, and that the less used in mixing, provided the mix is plastic, the stronger will be the resulting concrete. Tests have shown that the employment of a richer mix, say a 5 : 1 in place of a 7 : 1 may not produce a stronger concrete if an excess of mixing water is present. The concrete must always be plastic when put in place, but the degree of " sloppiness " must depend largely upon the use for which the concrete is required. For example, the mix for mass concrete can be made much less sloppy than for thin reinforced beams. In the past there has been great difficulty in gauging the sloppiness of concrete, and the degree of sloppiness has had to be left largely in the hands of the workmen. We have now available a method of measuring the sloppiness of concrete, known as the " Slump Test." The Slump Test apparatus consists of a mould of galvanised iron in the form of a cone with the base 8 inches in diameter, the top 4 inches in diameter, and the height 12 inches.

The mould is placed on a flat non-absorbent surface and filled with the freshly mixed concrete in four layers, each layer being puddled with a bullet nosed bar, and the top is struck off so that the mould is exactly filled. The mould is removed by raising vertically immediately after being filled.

The moulded concrete is then allowed to subside until quiescent and the amount in inches the concrete has decreased in height is the Slump.

With given materials, the amount of water required per batch can be determined by means of the Slump Test and then this amount of water can be measured for each batch. The Slump Test is easily carried out and can be performed by the foreman.

The following results from our own experience will illustrate the use of this test:—

A reinforced concrete silo was being built for us and throughout the work samples of the concrete were taken as it came from the mixer and made into test cubes which were broken at various ages. At first we found the men mixing concrete of such a sloppy nature that a slump of 10½ inches was obtained. We got into touch with the consulting engineers responsible for the work, and asked for the water to be cut down. They arranged this and smaller slumps of 4 to 6 inches were obtained. The compression tests of the cubes made from the concrete showed the stiffer concrete to have *more than double the strength of the sloppy concrete.*

The use of the excess water was doing nothing more or less than *wasting half the value of the cement.*

The following table shows the average results of the tests made :—

Slump in Inches.	Crushing Strength in pounds per square inch.	
	7 days.	28 days.
8½—10½	666	1460
5½—6½	1340	2770
4½	2010	3005

The separate constituents of concrete have now been briefly dealt with, but their dependence one upon another should be emphasised. Poor aggregate or poor cement needs a richer mix to produce the same strength as when good quality materials are used, or the concrete must be made more massive to give the same service A good quality cement will produce a good job with very questionable aggregate, but if the other constituents of the concrete are first-class, leaner mixes can be adopted or less massive concrete can be used.

The subject cannot be left without one or two words on the treatment of concrete after it has been laid. It is possible for concrete to be made out of first-class materials used in the right way, and yet fail, if it is not given proper treatment after it has been laid. For example, concrete, if subjected to frost while the first hardening is taking place, may fail; thin renderings subjected to hot, dry conditions without adequate protection, may fail through rapid drying out. The rapid drying out of floors will tend to bring on "dusting." These two causes of failure, out of many similar, can be readily prevented by a man who understands the nature of the materials he is dealing with.

Adulterants.—There is a tendency for adulterants to be added to the cement or water to obtain some particular effect; these additions frequently being made by the workmen without the authority of the Contractor. In many cases these admixtures are ill-advised, doing actual harm to the concrete, whilst in other cases the results may not be worth the extra cost.

In rendering work, cement mixed with certain sands may produce a very harsh-working mixture. The addition of Hydrated Lime, not exceeding 10% of the weight of the cement will facilitate the working attempt at the expense of a slight decrease in the strength of the material.

The addition of Plaster (*i.e.*, a Gypsum Plaster) should on no account be made, since it will bring about the disintegration of the rendering.

The use of salt in the mixing water to lower the freezing point is not to be recommended since the desired effect is only very slight and the strength of the concrete is greatly impaired. It should under no circumstances be added for reinforced work. The addition of Soda to quicken the set, reduces the ultimate strength of the concrete.

In conclusion we want to repeat our conviction that the study of concrete materials by the users would very much improve the standard of concrete work, as it would also reduce the cost. The cheapening of the cost would bring concrete construction into a still more favourable position in competition with other building materials, and the whole effect would be to hasten the development of the " Concrete Age " which is now most certainly beginning.

LABORATORY REPORT.

Portland Cement consists essentially of tri-calcium silicate, di-calcium silicate, tri-calcium aluminate, 5—3 calcium aluminate and di-calcium aluminate. The addition of water to tri-calcium silicate results in its partial decomposition to the di-calcium salt with the liberation of lime and since both the tri- and di-calcium materials are only soluble in water to an infinitesimal extent, the reaction is favourable to the formation of colloidal substances.

Regarding the aluminates, the tri-calcium aluminate is the stable one in contact with water and the lower lined salts are converted by the action of water into the tri-calcium product, with the liberation of alumina. Here again the products of reaction are in a colloidal state including the liberated alumina. These colloidal bodies are of the nature of a mineral glue, and absorption of water from them by the inner parts of the grains of cement causes the gradual contraction and stiffening of the jelly, and it is to this that the setting and hardening of the cement must be attributed.

After a period of, say, 28 days, the line which has been continuously evolved, crystallizes within the colloidal matrix, but one cannot trace to the presence of these crystals any of the strength developed by the cement. The aluminates are the first to hydrate and to them must be ascribed the setting and strength of cement up to a period of 24 hours. The tri-calcium silicate commences to hydrate after the first day, and continues till approximately the seventh, but the di-calcium silicate is the slowest to be effective, and the increase in strength after 28 days must be ascribed to the hydration of this product. Since hydration requires water, it can readily be appreciated that a complete drying out of concrete prevents further hydration and therefore prevents further development of strength, and continual growth in strength of concrete can only be obtained when there is sufficient water retained within the mass to hydrate the slowly reacting di-calcium silicate.

ECONOMIES OF LINE PLANT PROVISION.

[*The following extract, dealing with Teeing Systems, is taken from the paper on " Economies of Line Plant Provision," which was read by Mr. H. Kitchen before the London and several provincial local centres last session.*]

T*EEING Systems.* As mentioned earlier in the paper, a proportion of the conductors in Local Line cables are spare, and as this idle plant involves a considerable amount in annual charges, it will be agreed that any means of reducing this sum will be reflected in the financial results of the service.

With the present system of underground distribution, an ultimate efficiency of more than 75%, *i.e.*, of working to total wires in the cables, is not generally obtained with arrangements of joints. The alternative to very frequent reopening joints and rearranging the distribution of the spares is the provision of additional conductors, which increases the percentage of spare pairs, and is a more expensive and less efficient method of solving the problem.

To avoid opening plumbed joints several methods of teeing conductors have been tried, and latterly the auxiliary joint has been tentatively approved. Generally, the teeing arrangements have not proved satisfactory, and it is perhaps too early to pass judgment on the efficiency of the auxiliary joint arrangements. Auxiliary joints may, however, in some form or other, eventually become indispensable in congested areas, and there is plenty of scope for the application of a comprehensive form of teeing.

A system of teeing which has several new features and which will, it is hoped, minimise the drawbacks experienced with previously tried methods is under consideration.

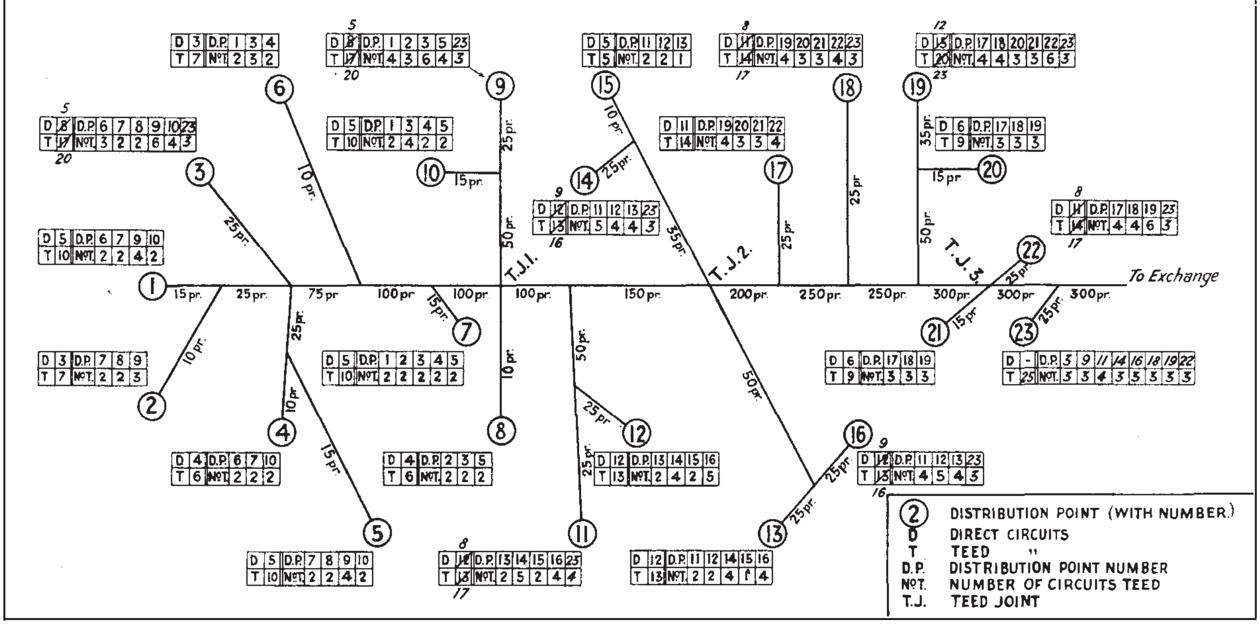
In the proposed system a group of D.P.'s is formed, each D.P. being either directly or indirectly interconnected with the others in the group by means of teeing so as to form the equivalent of the one large D.P.

Approximately 50% of the circuits in the main cable from the Exchange to the teeing point should be distributed direct to the D.P.'s, the remainder being divided so that each pair is made available at two D.P.'s by teeing at a common point. This will allow one-third of the circuits terminating at a D.P. to be connected direct to the Exchange and ⅔rds to be teed with other D.P.'s. The ratio, however, may be modified, if necessary, to suit local conditions. This method should generally give sufficient interconnection of the D.P.'s in a group to ensure that, before any D.P. area is regarded as closed to further orders, approximately 90% of the circuits in the main cable to the Exchange will have been brought into use.

The full capacity of the cables serving each D.P. will be carried forward towards the Exchange to a common point for each group from which point approximately ⅔rds of the capacity will be continued towards the Exchange, the balance being teed at this point. The number of D.P.'s to be interconnected will depend to some extent on the geographical relation of the D.P.'s to each other, a group being made up of D.P.'s which are reasonably close to each other. The primary essential, however, is that a fair number of D.P.'s be included in the group, say 5 to 10, so as to give the flexibility of a large D.P.

For example, a 50 pair cable might be provided to take into the Exchange 75 D.P. ends, or 100 pairs to take in 150 ends. Teed circuits from each D.P. should be spread over a reasonable number of other D.P.'s in the group and, although it is not proposed to connect each D.P. to every other D.P. in the group, the D.P.'s with which it is interconnected should be teed to other D.P.'s so that it may have access directly or indirectly to all D.P.'s in the group.

TEEING DIAGRAM No. I.


T.J.1.
T.J.2.
T.J.3.
To Exchange
DISTRIBUTION POINT (WITH NUMBER.)
D DIRECT CIRCUITS
T TEED "
D.P. DISTRIBUTION POINT NUMBER
No.T. NUMBER OF CIRCUITS TEED
T.J. TEED JOINT

The teeing point for each group should be at a convenient junction of the main and distributing cables.

Two long branches should not be teed together, a long branch should generally be connected to a short branch in order to minimise loss in transmission.

It is necessary that the ends of the leads of all teed circuits at D.P.'s should be carefully insulated by means of paper sleeves and lead caps soldered in position both initially and at any time when changes are made.

At D.P.'s, in addition to the ordinary numbering of pairs, the teed circuits should be marked by means of lead collets (compo piping) slipped over the leads and soldered in position so as to avoid the risk of being accidentally cut off when the leads are shortened.

The lead collets should be stamped with the letter " T " before being placed in position.

Examples of teeing are given in the attached diagrams, Figs. **1** and **2**.

Fig. **1** illustrates a typical case where new plant is to be provided, the total capacity of the branches being carried forward from the D.P.'s to the first teeing point, TJ1, from which 100 pairs in the main cable go forward to the Exchange.

Similarly at points TJ2 and TJ3 an additional 100 pairs go forward to the Exchange to serve each of these groups in which there are 135 and 140 ends respectively.

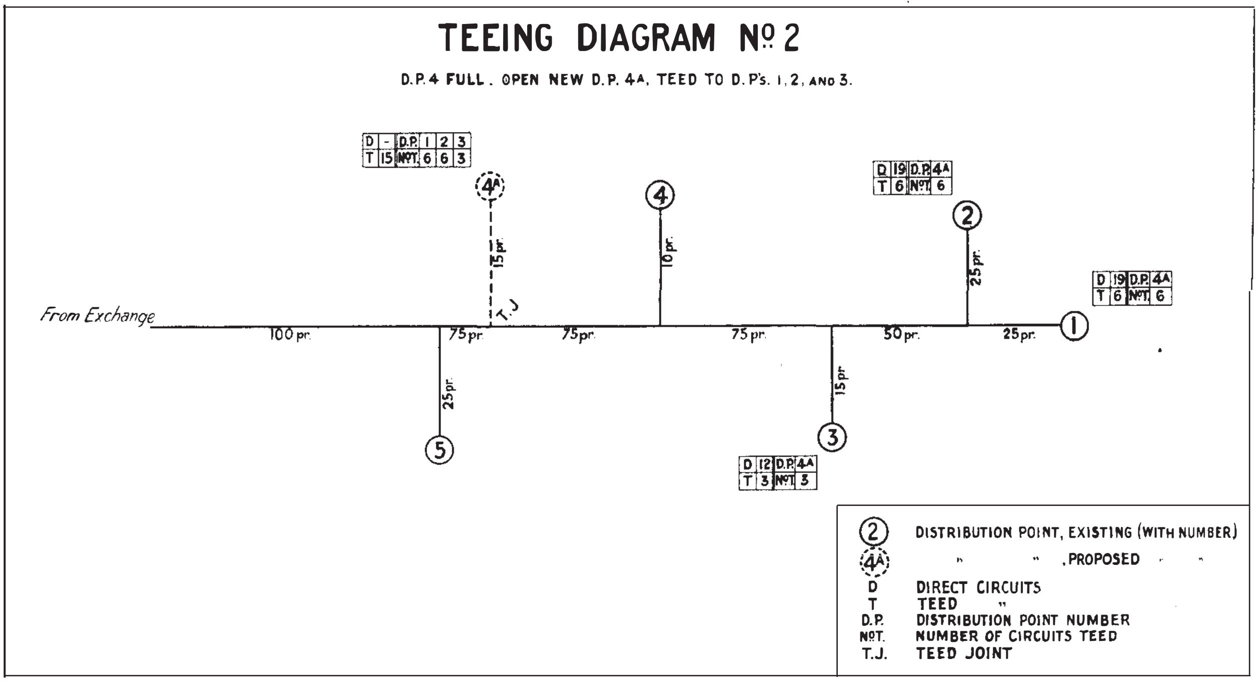
The diagram is thus divided up into several small groups each served by 100 pairs through to the Exchange, teeing being effected generally between D.P.'s within each group.

The 100 pairs serving the first group will provide 50 Direct and 50 Teed circuits, each teed pair being available to two D.P.'s, the difference in the number of pairs at the D.P.'s and the number taken through to the Exchange being 150 − 100 = 50. From the group of D.P.'s there will, therefore, be 50 ends taken direct to the Exchange and 100 ends teed, giving at each D.P. $\frac{1}{3}$ direct and $\frac{2}{3}$rds teed.

Each Teed circuit has to be made available at two points in the group, and in order to do this, the group should be divided into two portions having the same number of teed ends in each.

In the group served from TJ1 there are 150 ends, the Teed circuits can therefore be divided equally between the two halves of the group by taking half the total ends, in this case 75.

The first portion of the group will embrace D.P.'s 1 to 5 and the second portion D.P.'s 6 to 10; the requirements will therefore be met if 50 ends in the first portion are teed with 50 ends in the second portion.


TEEING DIAGRAM No. 2

D.P. 4 FULL. OPEN NEW D.P. 4A, TEED TO D.P's. 1, 2, AND 3.

In the example, this has been consecutively at D.P.'s 1, 2, 3, 4 and 5 by giving not less than two circuits to D.P.'s in the second half, in proportion to the size of the D.P.'s in the latter portion.

It will be seen that in the second group there are 135 loops taken into the Exchange on 100 pairs, carrying 35 Teed within the group, 10 Teed outside the group, and 55 Direct circuits. In this case the division of the group into two halves necessitates the division of D.P. 13 into two portions, 17 circuits of the 25 pairs at this D.P. are considered as belonging to the first half of the group, and 8 circuits to the second half.

The allocation of the Teed circuits is then made as before.

The last D.P., No. 23, is provided for entirely by Teed circuits from the groups already dealt with, taking a number of pairs from each group.

The effect of this is to reduce the number of direct pairs in each group; for example, in group No. 1 the number of direct pairs is reduced from 50 to 44, the difference, 6, being teed *outside* the group to D.P. 23.

The necessary adjustments of the figures are made at the D.P.'s concerned, as shown in the diagram.

It will be evident, therefore, that 450 pairs spread over the grouped D.P.'s are available on the 300 pair main cable at the Exchange. With this arrangement it may reasonably be anticipated that the whole of the capacity in the branch cable to any D.P. will be available to meet development without re-distributing at the joints.

Where the total capacity of a group of D.P.'s is small, in addition to providing intercommunication between D.P.'s in each group, increased flexibility will be obtained by providing Teed circuits from some D.P.'s in this group to D.P.'s in another group on the same main cable, thus in effect making two small groups into one larger group.

Diagram No. **2** indicates a method of teeing designed for cases where urgent relief is required in a D.P. area.

In this case it is assumed that all the available circuits on D.P.4 are working and that immediate relief is necessary. Sufficient spares exist in the main cable serving D.P.'s 1, 2 and 3 and a new D.P.4A is therefore opened with a capacity of 15 pairs which are teed over D.P.'s 1, 2 and 3. The distribution of these teed pairs is shown on the diagram and it will be seen that relief is afforded without the provision of any additional cable in the main route. The method illustrated might be adopted with advantage in cases where an individual D.P. area requires to be relieved, as the work involved generally would be less costly than the provision of additional circuits in the mains.

Records.—Provision is made on the D.P. card (T.E. 631) for recording Teed circuits and no difficulty is anticipated in making a complete and accurate record.

For each Teeing scheme a diagram similar to Fig. 1 will be necessary, and in addition, a schedule should be prepared for each Teed joint giving details of the disposition of each main cable pair in that joint which will be numbered in the ordinary way.

The diagram and the schedules will be filed together, and retained as a permanent record.

Teeing systems have been under consideration at Headquarters for a considerable period, and it is felt that the last word on this subject has not yet been uttered. The success of teeing as described is thought to be largely on the shoulders of the officers deputed to handle the actual work, and a great deal depends upon the accuracy of the plant records, particularly those contained on Cards T.E. 630 and 631.

Reference has already been made to the Auxiliary Joint method to obtain increased flexibility.

This system has been tried with success in London.

Briefly, the scheme is to stump out a selected joint, a number of pairs, say 25% to 30% of the capacity of the main cable feeding that joint. These pairs are numbered and left sealed in the stump until required. The remainder of the pairs in the main cable are distributed amongst the respective D.P.'s in the usual manner. The spare pairs in the branch cables from the D.P.'s to the same point are also collected in another stump so that the two stumps can be brought together to form a separate joint.

When relief is required at one or more D.P.'s the stumps are opened, and an auxiliary joint is made, the necessary pairs being joined through according to the D.P.'s needing relief. Variations in the requirements of individual D.P.'s are met by opening the auxiliary joint and redistributing the pairs as required.

Details of this method are given in Mr. Harvey-Smith's paper read before the London Centre, January, 1926.

THE 1927-28 CABLE INSTRUCTION COURSE.

A. Morris, M.I.E.E., and G. W. Hodge.

FROM October, 1927, to January, 1928, an instructional course was held in the Research Section of the Engineer-in-Chief's Office for the purpose of training officers of the Department in the capacity balancing and maintenance testing of underground cables.

One or more officers attended from almost all the Engineering Districts. The officers were drawn from the ranks of the Department's Inspectors, Probationary Inspectors, Repeater Officers and Skilled Workmen, the total number being 26.

In a previous article* particulars of similar courses which have been held in the past were described. The 1927/28 course was conducted along the same general lines as those described in the above-mentioned article. The course was divided into three parts in accordance with the subjects dealt with, namely:—

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* *"The training of officers of the British Post Office Engineering Department in Precision Testing of Underground Cables": Journal I.P.O.E.E., Vol. 19, part 2, July, 1926.*

Part A. Mathematical Introduction and Elementary Alternating Current Theory.
,, B. Cable Balancing and Acceptance Tests.
,, C. Cable Maintenance Tests and Localisation of Faults.

Part A, which was the first stage of the course, was taken by all the officers. The instruction given in this part was directed entirely towards the requirements of the subsequent lectures given in Parts B and C.

Certain of the officers had attended previous courses in either parts B or C and consequently were not required to attend that part of the course in which they had previously received instruction.

The syllabus for each part of the course followed very closely that described in the article previously mentioned.

The instruction was afforded in the first instance by means of a series of lectures, one lecture per day being normally given. During the progress of each lecture the officers made rough notes, which they subsequently transferred in full to the note-books furnished for this purpose. Notes of the more important features of some of the lectures were dictated to the officers. During the intervals between lectures, members of the teaching staff were in attendance in the class-room for the purpose of giving additional information and assistance, as well as help in the working of examples. In this way individual members of the class were encouraged to discuss and clear up the difficulties of previous lectures.

Upon completion of each of the series of lectures involved in parts B and C, a period of practical instruction was given for the purpose of familiarising the officers with the operation of the various pieces of apparatus and the testing methods described in the respective course of lectures.

The following schedules, which enumerate the tests and measurements actually made by each officer in parts B and C, will give some idea of the scope of the practical instruction which was given during the course.

THE 1927-28 CABLE INSTRUCTION CLASS.

Part B.

(i) The making of a quadruple selection for a 38 pair cable, commencing with the measured unbalances and proceeding in the usual manner to the calculation of the unbalance characteristics, the selection of cores to be jointed together and type of cross to be employed, the preparation of the jointing schedule and the application of the residual check.

(ii) Upon drum lengths of 308/20 M.T. cable and by the use of standard testing sets:—

(*a*) The measurement of within-core and between-core capacity unbalance. The initial balancing of the capacity unbalance set. The use of additional condensers for measurement purposes.

- (*b*) The measurement of within-core and between-core cross-talk in the open and terminated conditions.
- (*c*) The measurement of loop resistance and resistance unbalance.

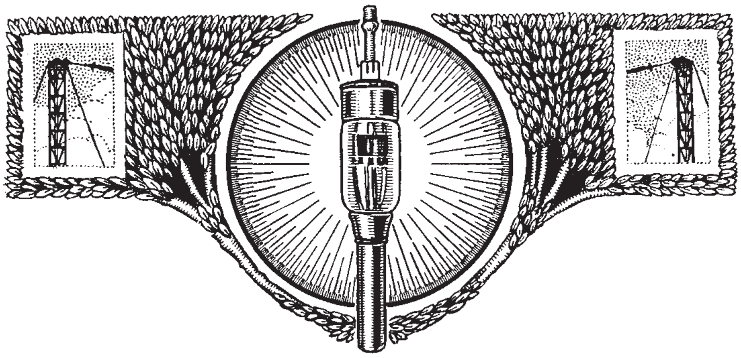
Part C.

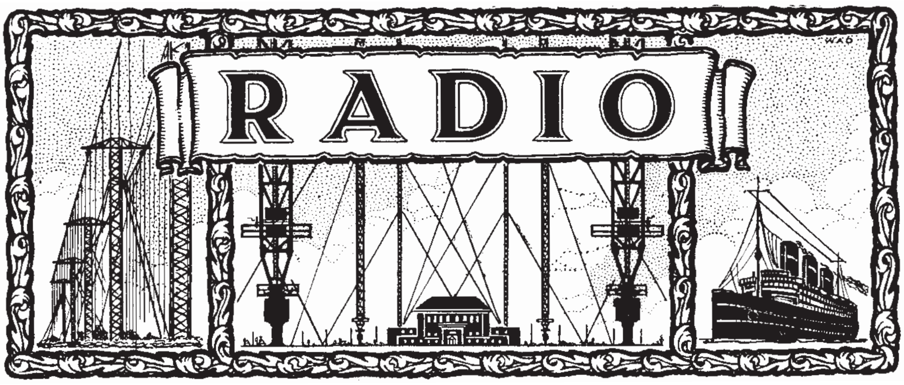
- (i) By means of a trunk cable resistance testing set with Unipivot galvanometer, and making use of artificial networks representing cable faults:—
  - (*a*) Localisation of earth fault and contact on long and short lines by Varley and Murray tests respectively.
  - (*b*) Localisation of conductor resistance fault on a long line by Reid test.
- (ii) By means of four dial Wheatstone bridge, reflecting galvanometer and auxiliary apparatus, and making use of artificial networks representing cable faults:—
  - (*a*) Setting up apparatus, testing for leakage from set and determining constant of galvanometer.
  - (*b*) Measurement of insulation resistance.
  - (*c*) Localisation of dielectric fault of high resistance (*i.e.*, of an incipient fault) fault on a short line by double-ended Varley test.
- (iii) By means of a 1000 ohm slide wire, reflecting galvanometer and auxiliary apparatus:—
  - (*a*) Localisation of incipient dielectric fault on a short line by double-ended Murray test.
  - (*b*) Localisation of disconnection in a long line by capacity charge and discharge methods.

As the various parts of the course were completed, each officer's fair note book was handed in for reading through and correction where necessary by the teaching staff.

With regard to part A previous knowledge of the subjects dealt with varied considerably in extent amongst the various members of the course. During the time allowed for the whole work it was impossible in the form of lectures to deal sufficiently fully with the subjects contained in this part, to meet the individual needs of all the officers. It is thought, however, that the lecture notes, supplemented by individual private study, have enabled the members of the course to obtain a good understanding of parts B and C.

An interesting memento of the course in the form of a group photograph is reproduced on the preceding page.





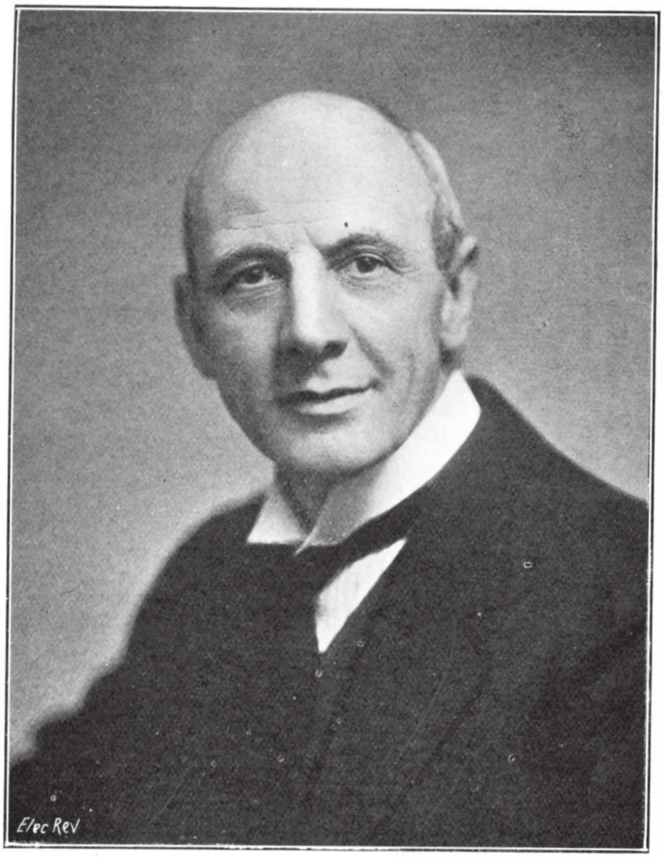
TRANSATLANTIC RADIO DEMONSTRATION.

JOINT MEETING OF THE INSTITUTION OF ELECTRICAL ENGINEERS AND THE AMERICAN INSTITUTION OF ELECTRICAL ENGINEERS.

A SIMULTANEOUS meeting of the two institutions was held on Thursday, 16th February, 1928, in London and in New York, the Transatlantic radio service forming the connecting link between the two gatherings. The London meeting began at 3 o'clock when a film entitled " Voices across the sea " was shown to a very large gathering in the large hall. The American Institution was holding its mid-winter convention in the Auditorium of the Institution in New York and at 3.25 p.m. (10.25 a.m. New York time) Mr. Waterson, of the A.I.E.E., concluded the reading of a paper on Transatlantic telephony. Mr. Charlesworth then explained the position in London to the New York meeting, while Col. Purves in the following words performed a similar service to the London audience :—

Col. Purves said : — " Mr. President and Gentlemen,—The American Institute of Electrical Engineers is holding to-day its mid-winter Convention in the Auditorium of the Institute in New York. Two papers on the subject of Transatlantic telephony are being presented there and Mr. Waterson, of the American Telephone and Telegraph Company, is now just on the point of completing the reading of the first of these papers. The joint meeting of the two institutions, in London and New York, will be held as soon as he has finished. We are using for the purpose the Transatlantic telephone system between Great Britain and the United States which has been in operation since January of last year and which provides regular public telephone service between the whole of the United States and a large portion of Canada on the one side, and the whole of Great Britain and several of the continental nations of Europe on the other. To-day we shall be using the Transatlantic radio link of about 3000 miles, and about 1200 miles of land line. The land line on this side connects us with our radio transmitting station at Rugby and with our receiving station at Cupar, in the Scottish Kingdom of Fife. On the other side it connects New York with the transmitting station Rocky Point, Long Island, and with the receiving station at Houlton, Maine. The local arrangements made at New York are exactly similar to those made here. Two loud speaking receivers are provided on each side, so that the audiences may hear the whole of the proceedings. The photograph of each speaker will appear upon the screen in the auditorium while he is speaking. I will now leave the control of the line and apparatus in the hands of Mr. Charlesworth, in New York, and he will place Mr. Gherardi, the President of the American Institute, in communication with our President, Mr. Page, here."

At 3.30 p.m. Mr. Charlesworth, having been connected to London, said " Good morning, Colonel Lee, is Mr. Page ready to talk ? " Col. Lee replied " Good afternoon, Mr. Charlesworth. Mr. Page is ready to talk and I will hand the microphone to him."



Mr. Archibald Page.
President of the Institution of Electrical Engineers.
Chairman of the Joint Meeting.
(The photo is by Elliot & Fry. The block has been lent to us by "The Electrical Review.")

Mr. Gherardi: "Good morning, Mr. Page."

Mr. Page: "Good afternoon, Mr. Gherardi."

Mr. Gherardi: "Mr. Page, it would give us great pleasure if, as President of the Institution of Electrical Engineers—the senior Society, founded in 1871—you would act as Chairman of this joint meeting."

Mr. Page: "I regard it as a great honour to be asked to take the chair on this historic occasion; it is also a gracious compliment to our Institution, and in accepting, which I do gladly, I desire to thank you, Mr. President, and the members of the American Institute of Electrical Engineers, most heartily.

I welcome all present at the meeting now in session, and venture to predict that the proceedings will prove exceedingly interesting and likely to live not only in our memories, but to be quoted by succeeding generations of Electrical Engineers as marking an important milestone in the advancement of electerical science. I am sure I interpret the desire of those assembled if I request Mr. Gherardi to address us, which I now do."

Mr. Gherardi: "Mr. President and Members of the Institution of Electrical Engineers; on behalf of the American Institute of Electrical Engineers, I extend to you greetings and our best wishes. We are meeting here in New York at our mid-winter Convention. In the auditorium of the Engineering Society's building in New York City, from which I am speaking, there are assembled about one thousand members of our organization from all parts of the United States, from Canada, and from other parts of the New World. It is with the greatest satisfaction that, as a result of the accumulated work of the scientist, the inventor and the electrical engineer, it is possible for us to hold this joint meeting—the first of its kind. It is with feelings of deep appreciation and respect that we think of the men who have exemplied the ideas of your organization—Faraday, Maxwell, Kelvin, and of the many others, past and present, who have contributed to electrical engineering and to the scientific foundations upon which it rests. These developments have been notable and have contributed in the greatest degree to the welfare of mankind. One of these developments is the age of electrical communication—the electric telegraph and the telephone. These have made communication independent of transportation and no longer subject to all of its difficulties and delays. By the telephone, distance has not only been annihilated, but communication by means of the spoken word has become possible. Starting in 1876 with instruments and line which, with difficutly, permitted communication over distances limited to a few miles, the telephone has been improved year by year until continents have been spanned, and at last even the limitations of the Atlantic Ocean have been overcome, and to-day telephone conversation between the two great capitals of the English speaking world is a reality. We are gratified that Transatlantic communication has made this meeting possible; it has added one more to the many ties existing between our two Institutions, and has added still another opportunity for friendly communication between us."

Mr. Page responded as follows: "Mr. Gherardi and gentlemen. Please regard me for the time being, not as chairman, but rather as representing the 13,000 members of the Institution of Electrical Engineers.

My first desire is to thank you, Sir, for your most kind message of good will to us all. In turn we hail the President and Members of the American Institute of Electrical Engineers with feelings of the utmost warmth and of everything included in the term of good comradeship. Owing to the hour at which it has been necessary to hold this meeting falling within the period when the bulk of our members have to be on duty elsewhere, we have perforce had to content ourselves with a smaller gathering in London than that composing your Convention. It is, however, of a thoroughly representative character, consisting of specially invited distinguished guests, the Council of the Institution, many of whom have travelled long distances to be present, and a large percentage of the members of our Wireless Section. The telephone must rank as one of the greatest inventions of the 19th century, and it has transformed the daily life of all civilised people. Our indebtedness to Graham Bell for the boon he has conferred upon us increases with the years, and his memory, along with that of Franklin and Henry, will be cherished as becomes such benefactors of mankind. It would indeed be a gigantic task to attempt to exhaust the list of those of your Society who have contributed so largely to the progress of Electrical Science and I must content myself by paying tribute to a great Institution which has given proof time and again that Engineering is truly International.

It cannot be questioned that we are living in a period of extraordinary change due to scientific discovery, and in no field has the advance been more marked than in that of the Communication Engineer.

The Commercial Radio services thus placed at our disposal assure closer and closer association between the English speaking races, a new spice is added to life and the bonds of friendship materially strengthened. I rejoice that our two Institutions can combine in the future even more effectively than in the past and that this is the outcome of the splendid work done in one of the branches of our own profession.

I will now resume my Chairmanship and call upon Dr. Jewett, who is one of the Vice-Presidents of the American Telephone and Telegraph Company and a past President of the American Institute of Electrical Engineers."

Dr. Jewett said: " Mr. Chairman, Mr. Gherardi, and fellow members of the Institution of Electrical Engineers and of the American Institute of Electrical Engineers, the opportunity which this occasion offers of addressing jointly two widely separated groups of engineers, who in times past have addressed each other *vis-a-vis* in London and New York, affords me the liveliest satisfaction.

I am gratified to participate in an event which marks both a notable advance in electrical communication and a pioneer demonstration of a wider use for electrical communication. I am frankly pleased that in common with numerous associates on both sides of the Atlantic it has been my good fortune to play a part in the development work which has made this occasion possible.

Col. Purves and Mr. Gherardi will remember and the rest of you will be interested to know that when in London more than a year ago we were engaged in a final consideration preliminary to the opening of commercial Transatlantic Telephony, we discussed details of just such a meeting as this. That our discussion should have been serious and not a pleasant mental diversion at a time when the channels of communication were not in operation is a striking evidence of the sound basis which underlies present day electrical engineering. The fact that we saw and appraised the many obstacles to be overcome did not in the least diminish the assurance with which we talked of and planned for a distant event.

While, therefore, the present occasion is highly gratifying to the engineers whose work has made it possible, it is in no sense a surprise.

Success of this occasion is significant also in that it is the tangible evidence of a co-operation both intimate and full between men so situated as to make co-operation difficult. On behalf of my associates in America, I salute our associates in England."

The Chairman then called upon Col. Purves, Vice-President of the Institution of Electrical Engineers and Engineer-in-Chief of the British Post Office.

Col. Purves said:—" Mr. President, Mr.

Gherardi, Dr. Jewett, and Gentlemen: It is an honour and a privilege to be associated with this notable event, which, one can justly feel, is breaking new ground in the advance of nations towards closer relationship. It is a great thing that two large assemblies separated by wide expanses of ocean, can join themselves together as we are doing now and interchange their thoughts and ideas by the simple and natural medium of direct speech to a combined audience. It opens up the prospect of results which thrill the imagination and which are bound to be beneficient, and to conduce, by the way of clearer mutual understanding, to the good of mankind. On this first occasion it is inevitable that the many professional interests which our two institutions share—and which we should dearly like to talk over with each other—should be pushed a little into the background, and that we should find ourselves preoccupied mainly with the wonder of the thing itself. At our meeting here in London we have just been shown a motion picture which illustrates in a very vivid and interesting way the initiation and progress of a Transatlantic telephone conversation between San Francisco on the Pacific Ocean and Plymouth in old England. We were not able—not yet able—to place it simultaneously before the eyes of you who are sitting there in New York, but some of you, at least, have seen it already. The greater part of it was made on your side and I have to thank your President very heartily for letting us have the completed film. It helps one to recall, and to visualise, the remarkable series of new electrical developments—most of them things of only yesterday—which have combined to make this evening possible.

The Radio art has given us its essential basic principles and the high-power amplifying tubes, which over here we call "Valves"; long-distance telephony has contributed a host of new devices which are equally essential; and specialised broadcasting has given us the loud-speaking receiver.

As we sit and talk to each other our speech is launched into the air, by the radio transmitting stations at Rugby and at Rocky Point, with an electro-magnetic wave energy of more than 80 horsepower, and I may add that the combined effect of the various refinements and special devices included in the transmitting and receiving systems is to make the speech-carrying efficiency of each unit of this power many thousands of times greater than that of an equivalent amount of power radiated by an ordinary broadcasting station. Many further improvements are still being studied.

I should like to express the feelings of great personal pleasure with which I am listening this evening to the voices of my old and valued friends of the American Telephone & Telegraph Co., Mr. Gherardi, Dr. Jewett and General Carty, and to assure them and their colleagues both on my own behalf and on behalf of the engineering staff of the British Post Office, that the increased opportunities of co-operation with them which the development of the Transatlantic telephone system has afforded us, are appreciated in a very high degree. We have to thank them for much helpful counsel, in this and in many other matters, and we look forward with great pleasure to a continuance of our close association with them on the long road forward, over which we still have to travel together."

The Chairman said:—" We are delighted to have with us in New York, General John J. Carty, Vice-President of the American Telephone & Telegraph Company and a past President of the American Institute of Electrical Engineers. General Carty is widely regarded as the doyen (or, to be more correct, the dean) of the telephone engineering profession, and we shall be glad if he will say a few words and propose a resolution on the subject of our joint meeting."

General Carty then proposed the following motion:—

" Whereas on this sixteenth day of February, 1928, the members of the Institute of Electrical Engineers assembled in London, and the members of the American Institute of Electrical Engineers assembled in New York, have held, through the instrumentality of the Transatlantic Telephone, a joint meeting at which those in attendance in both cities were able to participate in the proceedings and hear all that was said although the two gatherings were separated by the Atlantic Ocean; and as this meeting, the first of its kind, has been rendered possible by engineering developments in the application of electricity to communication by telephone; therefore;

Be it resolved that this meeting wishes to express its feelings of deep satisfaction that, by the electrical transmission of the spoken word, these two national societies have been brought together in this new form of International Assembly, which should prove to be a powerful agency in the increase of good will and understanding among the nations;

And be it further resolved that a record of this epoch-making event be inscribed in the minutes of each society."

The Chairman: "Sir Oliver Lodge, who needs no introduction, is sitting beside me, and I have asked him to second the motion."

Sir Oliver Lodge said: "It is surely right and fitting that a record of the transmission of human speech across the Atlantic be placed upon the Minutes of those Societies whose members have been instrumental in making such an achievement possible, and I second the proposal that has just been made from America.

All those who in any degree have contributed to such a result—from Maxwell and Hertz downwards, including all past members of the old British Society of Telegraph Engineers—will rejoice at this further development of the power of long distance communication. Many causes have contributed to make it possible:—

That speech is transmissible at all is due to the invention of the telephone. That speech can be transmitted by ether waves is due to the invention of the valve and the harnessing of electrons for that purpose. That ether waves are constrained by the atmosphere to follow the curvature of the earth's surface is an unexpected bonus on the part of Providence, such as is sometimes vouchsafed in furtherance of human effort.

The actual achievement of to-day at which we rejoice, and which posterity will utilise, must be accredited to the enthusiastic co-operation and to the scientific and engineering skill of many workers in the background whose names are not familiar to the public, as well as to those who are well known.

The union and permanent friendliness of all branches of the English-speaking race, now let us hope more firmly established than ever, is an asset of incalculable value to the whole of humanity. Let no words of hostility be ever spoken."

The Chairman: "Gentlemen, you have heard the Motion proposed by General Carty and seconded by Sir Oliver Lodge. I now put it to the Joint Meeting.

Those in favour. All.
Contrary. None.
Carried unanimously.

The Chairman: "I suggest, Mr. Gherardi, that we now adjourn the meeting. I feel that it has been eminently successful and that we should regard it as the forerunner of many more to come."

Mr. Gherardi agreed.

The Chairman: "That is all the business, gentlemen. The meeting is adjourned. Good-bye."

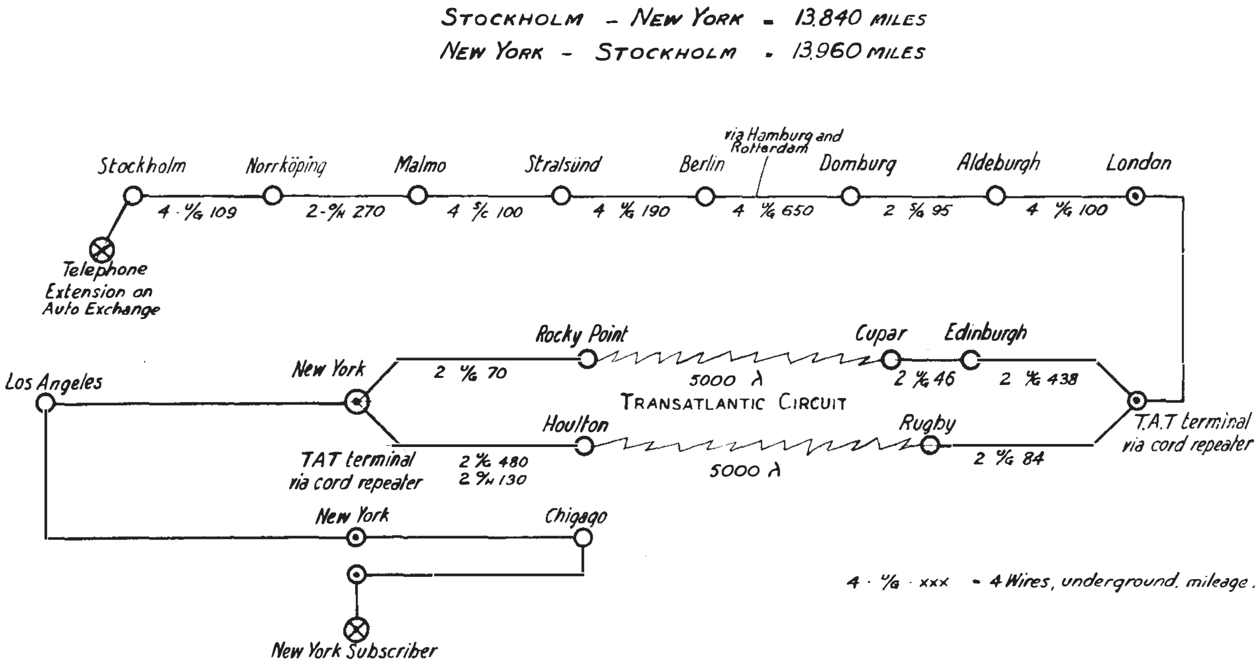
THE LONGEST TELEPHONE CIRCUIT—VIA TRANSATLANTIC SERVICE.

DURING a recent visit to Stockholm in connection with the extension of the Transatlantic Service to Sweden, a long distance test call was arranged by the London TAT engineers in conjunction with the A.T. & T. Co. engineers in New York. The trial was intended to determine the possibilities of interconnecting long wire circuits with the TAT circuit, and to find if there were any limit to such connections on account of transient phenomena. Accordingly, a circuit was built up which was routed from Stockholm-Berlin-London-New York-Los Angeles-New York-Chicago-New York. The technical features of this circuit include:—

Stockholm-Berlin-London.

1050 miles 4-wire U/G extra light-loaded cable.
270 miles 2-wire O/H.
100 miles 4-wire sea cable (Baltic Sea).
95 miles 2-wire sea cable (North Sea).

This circuit includes 25 four-wire repeaters with cord repeaters at London and Berlin, and with two echo suppressors.



London-New York (TAT).

This is a 4-wire circuit with

440 miles U/G medium-loaded cable 120 miles U/G extra light-loaded cable 3200 miles radio circuit	New York to London
570 miles U/G extra light-loaded cable 130 miles O/H 2920 miles radio circuit	London to New York

There are 9 two-wire repeaters toward London, 10 toward New York, 2 four-wire terminal repeaters and there is an echo suppressor at each end of the circuit.

New York Exension.

The special loop in the United States, comprising a Los Angeles loop and a Chicago loop, included :—

4844 miles extra light-loaded cable.
3864 miles open wire carrier.
90 four-wire repeaters.
16 intermediate carrier repeaters.
8 terminal carrier repeaters.
4 cord circuit repeaters.
4 echo suppressors.

This means that the total circuit length was some 13,980 miles toward Stockholm and 13,840 toward New York. There was a total of 115 four-wire repeaters, 24 carrier repeaters, 6 cord repeaters in the wire circuits, and 2 four-wire and 19 two-wire repeaters in the TAT circuit. The circuit included 8 echo suppressors, and finally there were the two radio transmitters and the radio receivers.

The overall circuit was approximately calibrated to be 20 TU, or 2.3 βl, and under the fairly good radio conditions existing at the time of the call the circuit was sufficiently stable for the recognition of persons by their voices. There was no marked trouble from transients, which, if present, are always emphasised by the false operation of the special switching devices at London and New York on the TAT circuit. In view of this result there would seem to be no reason why a similar composite circuit as was extended on the TAT circuit in New York could not be added at the London terminal. If so, we have reached the stage when telephone conversation with high grade lines or carrier systems, interlinked if necessary by radio-telephone circuits, is possible over a range of 21,000 miles at least.

THE "EMPIRADIO" BEAM STATIONS.

A FEW years ago the detached observer might well have formed the opinion that the stage was set for a long controversy as to the relative advantages of long wave and short wave telegraphy for long distance radio communications. There was a serious danger that the continued advancement of this country in the forefront of radio progress would be jeopardized by a failure to realise that for particular purposes each was invaluable, and that the two extremes of the art of radio communication were in fact complementary.

Fortunately, however, following the completion of the Rugby High Power, Long Wave Radio Station, it was decided to proceed with the "Empiradio" Beam Stations.

The construction of the group of stations in this country operating on the Beam system for communication with Canada, South Africa, India and Australia, is the outcome of an agreement made between the Postmaster-General and Marconi's Wireless Telegraph Co. in July, 1924, in which a guarantee was given that effective speeds both of sending and receiving simultaneously at 100 words per minute during a daily average of 18, 11, 12 and 7 hours respectively would be obtained.

The grouping of the stations is in two pairs. Bodmin is a two-beam transmitting station for Canada and South Africa with its corresponding receiving station at Bridgwater, while Grimsby and Skegness are similarly the transmitting and receiving stations for India and Australia.

In determining the location of the stations consideration was first given to the practicability of combining all the transmitters at one site and the receivers at another. The conditions to be met, on the one hand, of avoiding possible interference with broadcasting and other services, and on the other, of ensuring a free path in the immediate proximity of the aerial system clear of trees, buildings and hills were too onerous to permit this ideal solution to be found. To meet the latter condition it was stipulated that there should be no obstruction in front of the aerial subtending an angle of more than six degrees above the horizontal.

A further consideration was the necessity of locating the receiving station a sufficient distance from the transmitting station, and clear of the direct path of the outgoing beam, to avoid interference from this source. The selection ultimately made of locating the Canadian and South African Stations in the South-west of England gives a very short travel overland in the direction of the distant stations before clearing the coast line. The same conditions apply for the Indian and Australian Stations on the North-east coast, except that in the case of Australia as propagation is made alternatively in two directions 180° apart one path is necessarily across England. During the period approximately midday to midnight transmission to Australia is in an easterly direction, *i.e.*, the shorter great circle path, whilst from midnight to midday transmission is in the opposite direction, which, although longer, is chiefly over sea.

All of the sites meet the conditions of being flat, free from woods and buildings or from abrupt changes of contour in the immediate area.

Alternative wave-lengths are used for each transmitter except that for Australia. Those at present employed are:—

To Canada ...	16.574 m.	32.397 m.
,, S. Africa ...	16.146 m.	34.013 m.
,, India ...	16.216 m.	34.168 m.
,, Australia ...	25.906 m.	
From Canada ...	16.501 m.	32.128 m.
,, S. Africa...	16.077 m.	33.708 m.
,, India ...	16.286 m.	34.483 m.
,, Australia ..	25.728 m.	

Buildings.—The main buildings at Bodmin, which are steel framed with concrete walls, are divided into three sections (*a*) Power House, Battery room and offices, 116′ by 57′; (*b*) Transmitter room, 38′ by 34′; (*c*) Absorber and oil pump house, 26′ by 16′. The latter is used to accommodate the absorber resistances, Sturtevant blowers for cooling these resistances, blowers for cooling the seals of the Main Valves, pumps for the circulation of paraffin through the jackets of Main Valves.

The Transmitter room is connected to the Power House by a short covered passage, the continuity between the two buildings being broken in order to avoid the transmission of vibration from the engines and machines to the transmitters.

The buildings at Grimsby are constructed of brick and are similar to those at Bodmin, with the exception that accommodation is not required for oil engines and a separate building is provided for terminating the outside power supply.

At the Bodmin Station the main power supply is provided by three Ruston and Hornsby, three-cylinder, vertical, heavy-oil engines, each giving 165 B.H.P. at 300 revs. per minute and directly coupled to a 92 K.W. compound-wound dynamo delivering D.C. at 440 volts. These engines, which have special 7 ton flywheels, are mounted on a large concrete block supported on cork pads to minimize the transmission of vibration and carried on a concrete raft. The engines are started up by means of two air compressors driven by small auxiliary petro-paraffin engines, air being stored in two containers at 300 lbs. per sq. inch.

The Grimsby Station obtains its power supply from the Grimsby Corporation Electricity Works at 6000/6600 volts, 3-phase, 50-cycles, which is transformed to 400 volts, 3-phase, by means of three 83 K.V.A. single phase transformers. The auxiliary machines at Grimsby are driven by induction type motors, 400 volt, 3-phase, 50-cycles.

With the exception of the power supply the transmitter details are similar at both stations.

The receiving stations are each equipped with two 18 H.P. two cylinder, petrol-paraffin engines direct coupled to 10 K.W. Dynamos, supplying power at 165/110 volts for battery charging and lighting. The general design of all the receivers is the same, with the exception already noted that provision is only made for one wave-length reception from Australia.

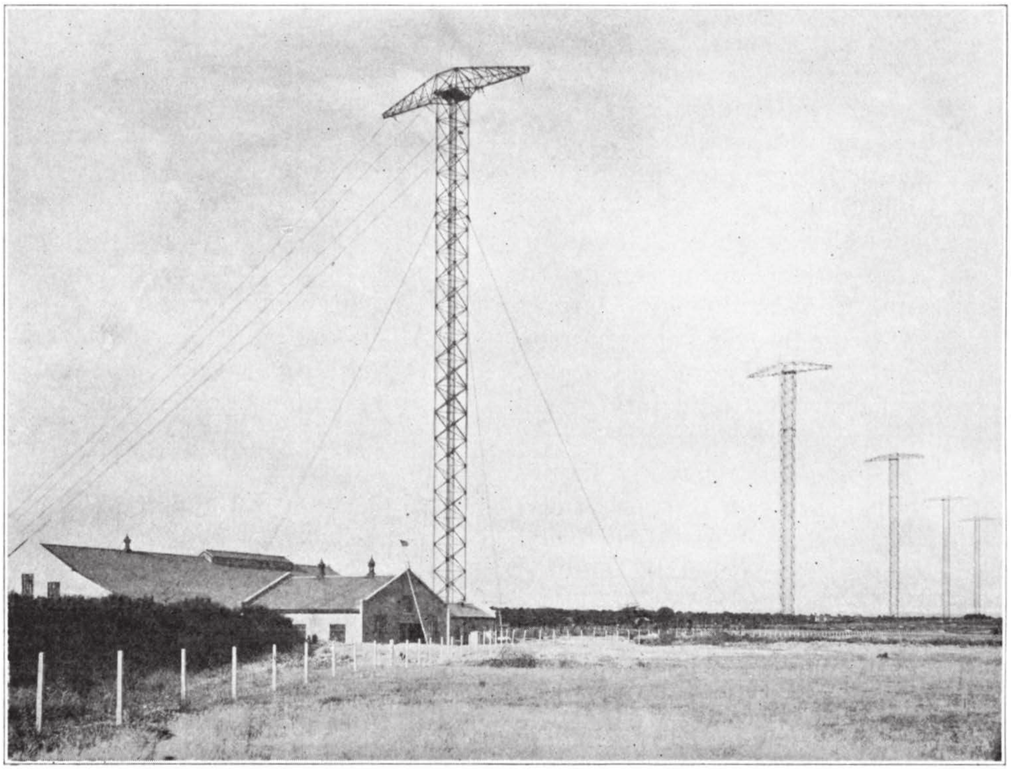


FIG. 1.—BODMIN BUILDINGS AND SOUTH AFRICAN MASTS.

The essential differences between the stations having been noted above, the detailed description will be confined to the Canadian and South African groups.

Site.—The Bodmin transmitting station is about $4\frac{1}{2}$ miles from Bodmin and borders the main road from there to Truro. The total area enclosed for the buildings and aerial system is about 43 acres.

Fig. 1 shows the buildings and the South African masts.

Water Supply.—Water for engine cooling and domestic purposes is obtained from two bore holes on the site.

Storage capacity and cooling is provided for by a ferro-concrete reservoir having a capacity of 30,000 gals.

Power.—All the auxiliary generators are driven by 440-volt direct current motors. They comprise:—

1. Three alternators, each having an output of 50 K.V.A. single phase, 1000 volts, 300 cycles, which supply the main high tension power at 7000 to 10,000 volts to the anodes of the transmitting valves after transformation and rectification.
2. Three alternators, each having an output of 1.2 K.V.A., single phase at 220 volts, 500 cycles, for high tension supply at 2000 volts to the anodes of the valves in the drive or master oscillators, and the first amplifier stage.
3. Two "rectifier filament" alternators, each having an output of 20 K.V.A. single phase at 500 volts, 300 cycles, for heating the filaments of the valves in the Rectifying Panels. The 500 volts is transformed down to 11-12 volts.
4. Two "magnifier filament" generators, each having an output of 18 K.W. D.C. at 24 volts to supply the filaments of all the oscillator valves in the main oscillators, No. 2 Magnifier, and the Main and Sub-Absorber Valves.
5. Two D.C. generators, each having an output of 8 K.W. at 100/165 volts for lighting and control circuits.

Fig. **2** shows the layout of the engine and machine room.

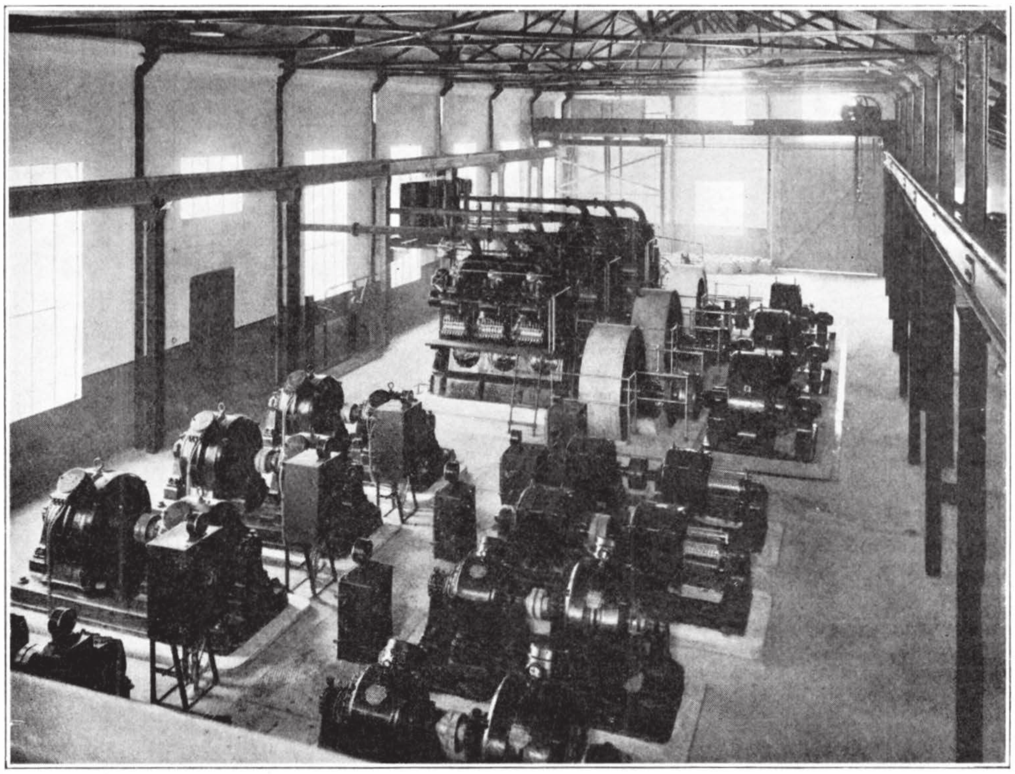


FIG. 2.—BODMIN ENGINE AND MACHINE ROOM.

Batteries.—In addition to a stand-by lighting battery, special filament lighting batteries are installed for the master oscillator and No. 3 magnifier. These batteries are provided with a discharging resistance and are only put on load over the flat portion of the discharge curve, to ensure constancy in the master oscillator.

400 volt, 5 amp.-hour batteries are supplied for negative grid voltage to the magnifier and sub-absorber valves.

Rectifiers.—One main rectifier and one drive rectifier is provided for each transmitter. Each main rectifier comprises 16 Marconi MR 7A valves associated with smoothing chokes and condensers and step-up transformer for converting from 1000 volts at 300 cycles to 10,000 volts.

The drive rectifiers comprise 2 Marconi MR 7A valves and supply up to 3000 volts D.C.

Fig. **3** shows the Rectifier panels. The transformers and smoothing plant are mounted behind the rectifiers, and the whole is contained in a "high tension enclosure" in a corner of the Machine Room.

Transmitters.—Fig. **4** shows the Canadian transmitter on one side and the South African transmitter on the other, with the Control table in the centre.

The transmitters as shown in the photograph have the protective screening in front of the panels removed.

The transmitters are specially designed to ensure stability of wave-length and are controlled by Master oscillators. Constancy of wave-length is obtained (*a*) by careful screening of the master oscillator; (*b*) by a bridge method of connecting the amplifiers whereby the internal capacity between the grids and anodes of the valves is balanced, either by paralleling with a second valve acting in push-pull as in the second and final stages of amplification, or with a balancing condenser as in the case of the first stage; (*c*) and by an absorbing circuit which ensures constancy of load on the power supply during both marking and spacing.

The Master oscillator, which has an anode input of 160 watts, is screened in a copper box. The valve, which is air cooled of type T.250, is self-oscillating and drives the grid circuit of No. 3 magnifier.

No. 3 Magnifier, which provides the first stage of amplification, operates on an anode input of 2000 volts and a feed current of 90 milliamperes. The valve, which is a Marconi M.T.10, is effectively screened in a similar manner to the master oscillator and is coupled to No. 2 Magnifier.

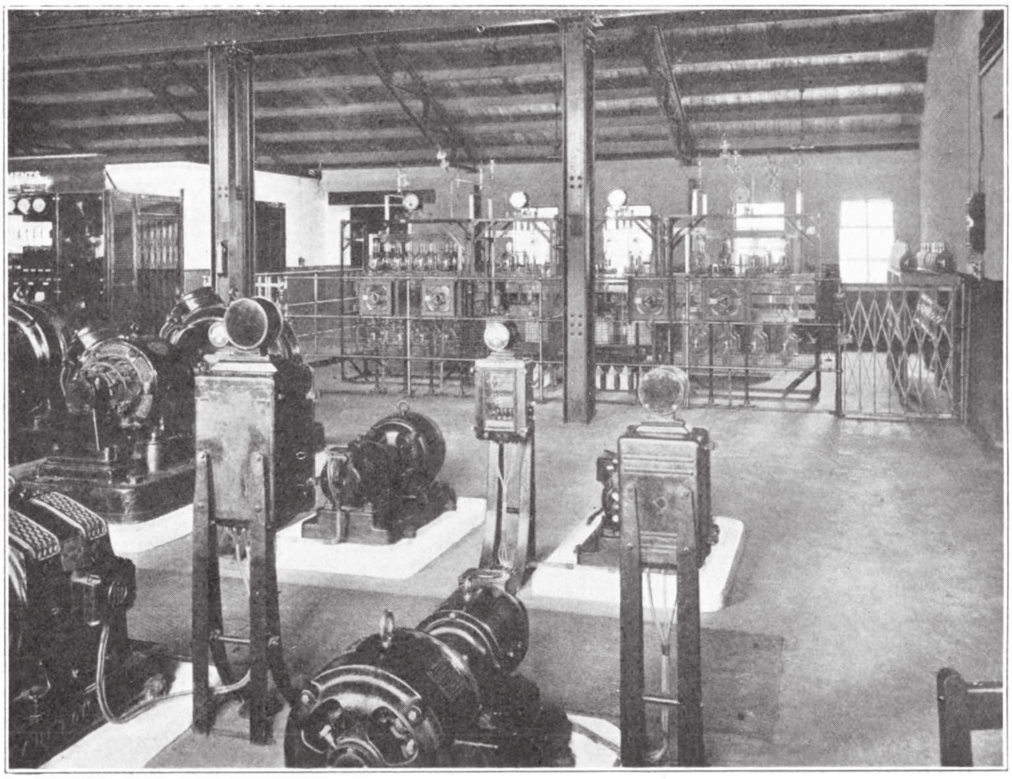


FIG. **3**.—BODMIN. RECTIFIERS.

No. 2 Magnifier, which supplies power to the grids of No. 1 Magnifier has two M.T.9F air-cooled valves, the anode supply being taken from the 10,000 volts D.C. supply through resistances. In the marking condition the anode voltage is about 5,500 and the feed 150 milliamperes. In the spacing condition the high

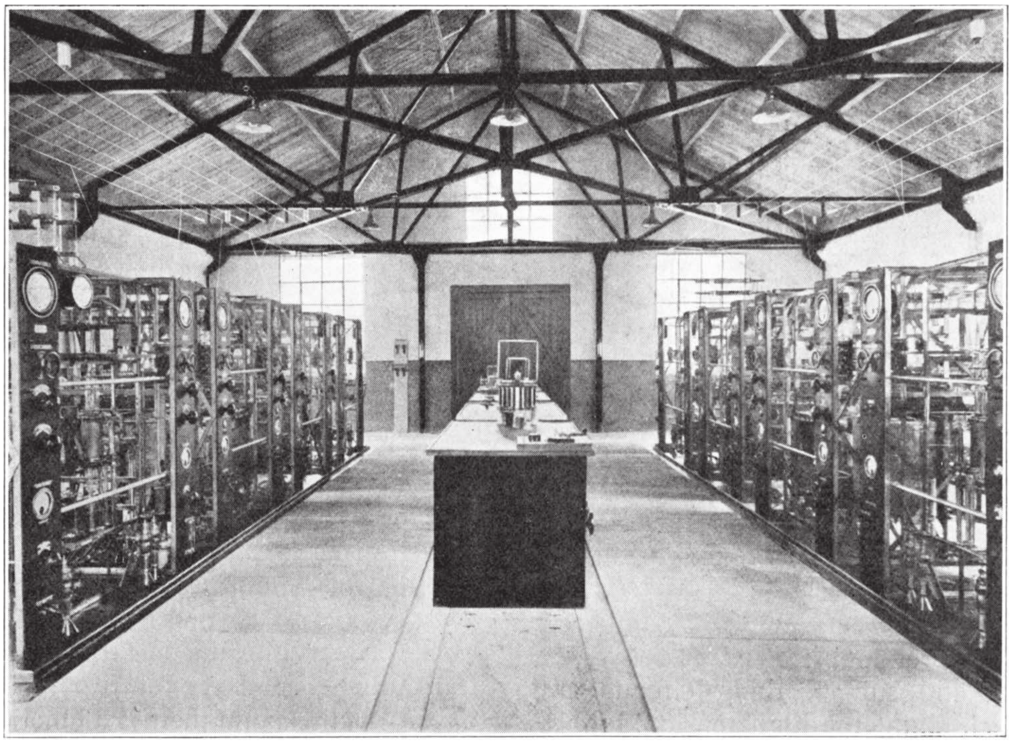


FIG. **4**.—BODMIN. CANADIAN AND SOUTH AFRICAN TRANSMITTERS.

tension supply is shunted through the absorber circuits and the oscillation is so reduced that No. 1 Magnifier does not oscillate. The normal grid bias of No. 2 amplifier is approximately 200 volts.

No. 1 Magnifier, the final stage of amplification, has two Marconi type C.A.T.2 Metal-Glass, oil-cooled valves, the filament voltage being about 20 volts and a current of 50 amperes per valve, which is supplied from a 24 volt D.C. Motor Generator.

The high tension D.C. Supply is at from 7000 to 10,000 volts, the feed current being about 1.1 amperes per valve, and the negative grid bias approximately 400 volts under normal working.

The valve seals are cooled by air blast and the anodes are cooled by a closed circulating system of paraffin oil. About 300 gallons of oil, per valve per hour, is circulated and this is cooled by means of coils submersed in water tanks.

The C.A.T.2 Cooled Anode Valves are rated to take an input of 10 K.W. at 15,000 anode volts and are specially designed for short wave transmission, in particular characterised by high insulation and low inter-electrode capacity.

Fig. **5** shows (*a*) Master oscillator (bottom right); (*b*) No. 3 Magnifier (bottom left); (*c*) No. 2 Magnifier (upper half of panel).

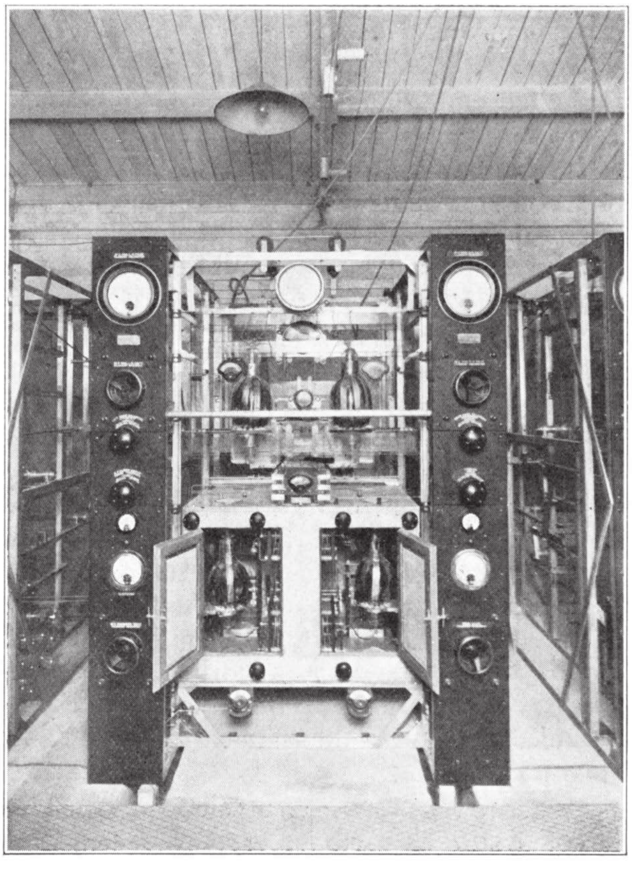


FIG. **5**.—MASTER OSCILLATOR, NOS. 2 AND 3 MAGNIFIERS.

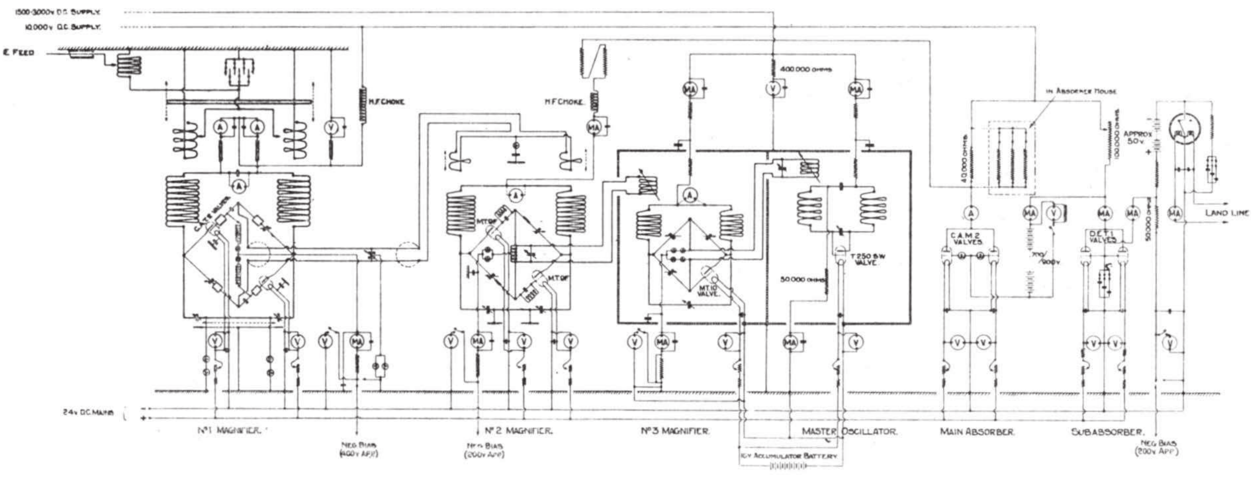


FIG. 6.—DIAGRAM OF TRANSMITTER.

Keying.—Fig. **6** is a diagram of a complete Transmitter.

The keying arrangements are designed to keep the load on the power supply constant, for which purpose main and sub-absorbing circuits are provided, which shunt the high tension supply by means of two type C.A.M.2 oil-cooled, metal-glass valves in parallel through resistances during the spacing periods, and simultaneously drop the voltage on No. 2 magnifier to about 600 volts.

The land line signals pass through an A.T.M. relay, and the spacing and marking currents are arranged to make the grid of the C.A.M.2 Valves conductive or non-conductive by throwing their grids positive or negative. These effects are stepped up through a circuit called the Sub-absorber which has two type D.E.T.1 Valves in parallel.

The main absorber resistances are housed in a separate room and are air cooled by Sturtevant blowers. These resistances are designed to dissipate from 20 to 24 K.W. of energy.

Controls. — The control tables, which are shown in the centre of the Transmitter room, carry three potentiometer type regulators for the control of the voltage of each main power alternator, and also three similar regulators controlling the voltage of the drive power alternators. In addition variable resistances are provided to control the filament current to the valves.

Feeder System.—A completely independent feeder system is used for each wave-length on each transmitter. Fig. **7** shows the two feeders serving the South African aerials at Bodmin. Two bays are allocated to the aerial system for each wave band, and one feeder runs from the transmitter room to the centre point of each pair of bays. At this point there is a junction box which divides into two branches, one going to the centre of each bay. Here there is another junction box and the feeder is again divided equally and branches as before, the process being repeated until there is one branch for each pair of aerial wires. This arrangement ensures that the length of feeder from the transmitter to each aerial wire on one particular aerial system is exactly the same. The feeder terminates at an aerial coupling box containing an auto-transformer, from which an individual feed is made to each aerial wire.

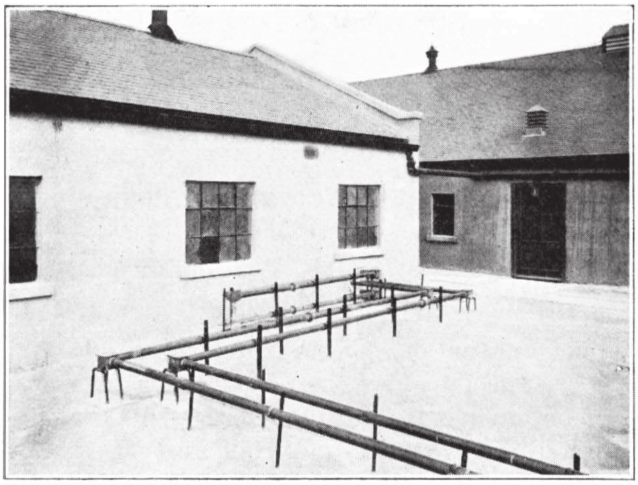


FIG. 7.—BODMIN. FEEDERS FOR SOUTH AFRICAN AERIALS.

Fig. **8** shows a typical layout of the feeder system for wave-lengths of 30-35 metres.

The aerials and feeders are so balanced and adjusted that the sum of the system acts as a pure resistance load on the transmitter so that there is no reflecting wave up and down the feeder system. To ensure this condition, at a point near the transmitter house two loops of feeder tube are so arranged that 3 high frequency thermo-ammeters come into proximity although situated at distances 32 feet apart along the feeder. Reflected waves are indicated by different readings on the 3 ammeters. The feeders consist of two concentric copper tubes air-insulated, the outer being earthed and carried on iron standards driven into the ground, whilst the inner is insulated by means of porcelain spacing insulators.

Special precautions have been taken to provide for expansion due to variations of temperature. Spun metal expansion joints are inserted every 16 ft. on the outer tubes and special boxes are provided at every 160 ft. to allow for expansion on the inner tubes.

At the Transmitting Station the outer tubes vary from $3\frac{1}{4}$ to $2\frac{1}{2}$ inch internal diameter and the inner tubes from 7/8 to 11/16 inch outside diameter.

Masts and Aerials.—Ten masts have been erected at Bodmin and Bridgwater, five being used for the service to Canada and five for South Africa, two bays being utilised for each wave-length.

At Grimsby and Skegness eight masts have been constructed, as only one wave-length is provided for communication with Australia.

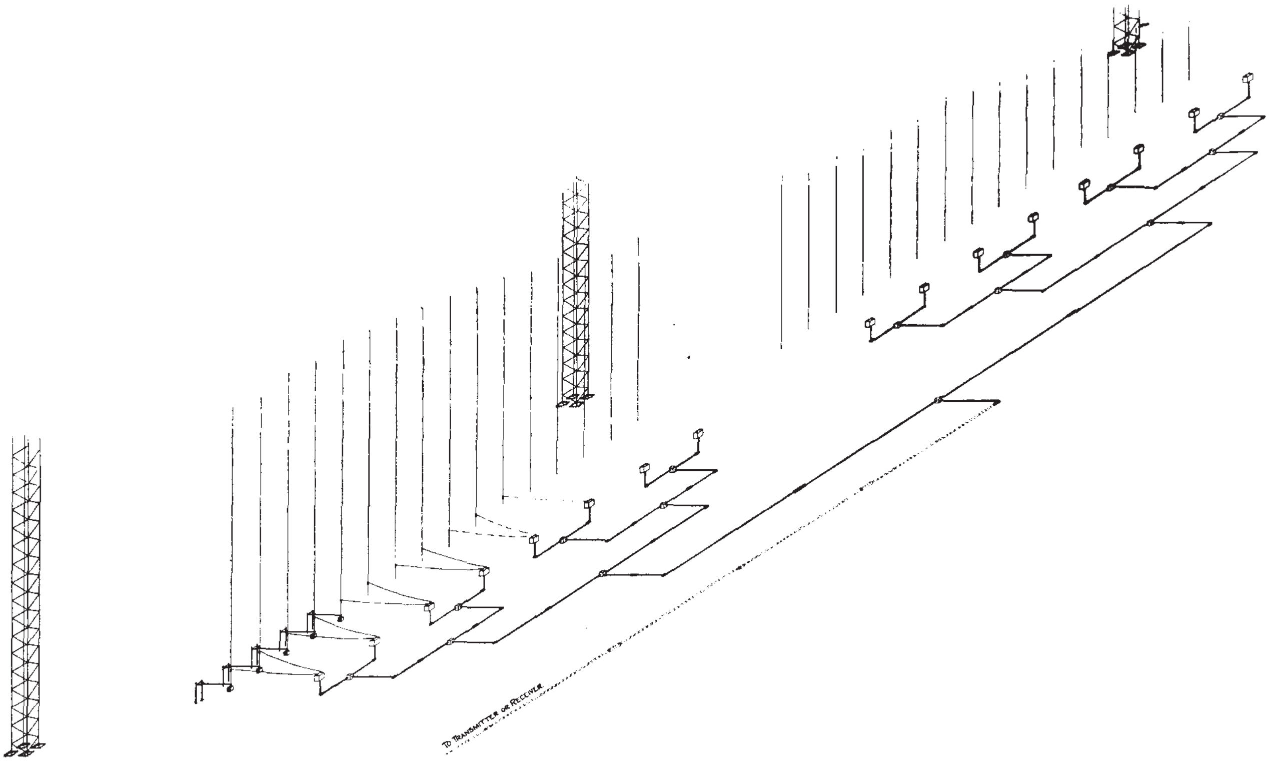


Fig. 8.—Schematic Diagram of Feeders, Long Wave Bays.

Each row of masts is arranged in a line at right angles to the great circle bearing of the distant station. The masts are of steel-lattice construction with an overall height of 287 feet, except in the case of the Australian masts which are 260 ft. The cross arms are 90 ft. long and also of steel-lattice construction.

Each masts has four legs and cross bracing of angle section, the vertical members being made up of 5″ by 5″ by $\frac{3}{4}$″ angles. The legs are attached by holding down bolts to concrete blocks, each 8 ft. square. The centres of the concrete blocks are 12 ft. apart and the masts are 12 ft. square throughout their length.

The masts are spaced at 650 ft. and each is provided with one set of 4 stays attached at 216 ft. above the ground.

The end masts have also 4 back stays to balance the strain of the triatics.

The aerial and reflector wires consist of a number of vertical wires of No. 16 S.W.G. copper clad steel, suspended from triatics which are attached to the cross arms, the aerial wires being in front of the masts and the reflector wires behind in the direction of propagation.

Inductances are inserted in the aerial wires, and the reflector wires are broken up into insulated sections, the number of wires, their distance apart and the number of inductances being dependent on the wave-length employed.

As a typical example the following are the particulars of the Canadian short-wave bays:—

There are 24 aerial wires spaced at 19′ 0″ apart and twice the number of reflector wires; the latter are spaced at 9′ 6″ and staggered in respect to the aerials so that the projection of an aerial wire on the reflector plane is midway between two wires.

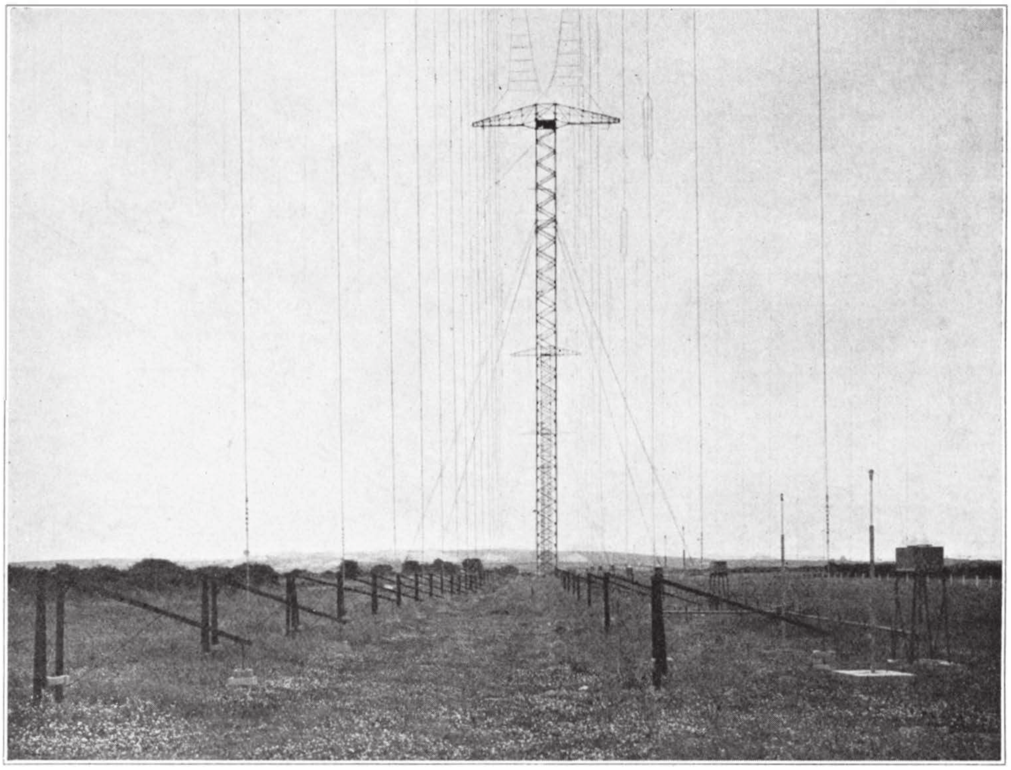


FIG. 9.—BODMIN. CANADIAN AERIALS AND BALANCE WEIGHT SYSTEM.

The triatics are suspended on the double catenary suspension system, and tails of varying length are inserted between the triatics and the aerial and reflector wires to allow for sag in the triatics and to ensure that the average height of the wires follows the contour of the ground surface.

As will be seen from Fig. **9** each vertical wire is brought down to a point within a few feet from the ground, and balance weights are provided to ensure an even tension on each individual wire and to minimise the movement of the wires during high winds.

The distance between the line of aerial and reflector wires is 40 ft., or slightly greater than $\frac{3}{4}$ of a wave-length. In the case of the longer waves the distance is reduced to about $\frac{1}{4}$ wave-length. Each vertical aerial is divided into three straight sections separated by phasing inductances. These lengths are unequal and vary from $\frac{5}{8}$ of a wave-length at the top to about $1\frac{3}{4}$ wave-length from the bottom inductance to the auto-transformer.

The reflector wires are divided into 8 insulated sections, each approx. $\frac{1}{2}$ wave-length in length.

The Australian beam system of reflectors is somewhat different, in this case the wires are in one uninterrupted length earthed at the bottom.

Receivers.—The aerial and transmission lines for the receivers are nearly identical with those used for the transmitters. The buildings for housing the receiver are in two sections, the engine room, and the receiving room and offices, which are joined by a short covered passage but with the continuity broken to avoid the transmission of vibration from the engines to the receivers.

The special characteristics of the receiver are the constancy of the output of rectified current to the line relay under varying amplitude of signal and slight changes of frequency.

It comprises 10 units, each contained in a copper screened box.

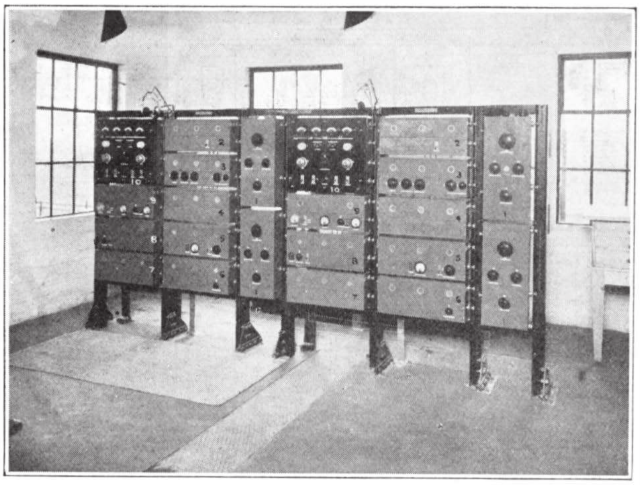


FIG. **10**.—TWO COMPLETE RECEIVERS.

Fig. **10** shows two complete Receivers. The units are:—

1. Feeder Terminal Unit. (In duplicate).
2. Modulator.
3. Incoming short-wave circuits and first hetrodyne.
4. First filter amplifier.
5. First rectifier, second hetrodyne and first listening circuit.
6. Second filter amplifier.
7. Additional second filter amplifier.
8. Main rectifier and second listening circuit.
9. Recorder and limiting circuits.
10. Switchboard for valve testing.

The units are mounted on a vertical iron rack, connections between the units being made at the back, all tuning controls and switches being arranged on the front.

Fig. **11** is a diagram of a complete Receiver.

The feeder terminal unit, where the aerial system is joined to the receiver, has two tuned intermediate circuits which can be weakly coupled together. The second intermediate circuit has a variable coupling to the input circuit of the receiver, which is tuned to the frequency of the transmitted wave and is connected to two modulating valves worked in push-pull. Coupled to this circuit is the first hetrodyne circuit which produces a beat wave of about 1600 metres. The signal on the new frequency has three stages of high frequency push-pull amplification, designed to give a constant amplification over a 10,000 cycle band with a sharp cut-off outside the band. Following the three stages of high frequency amplification, the signals are rectified and again hetrodyned. This second hetrodyne is used alternatively by means of a switch for giving an audible beat frequency or for changing the wave-length to about 10,000 metres. A further three stages of high frequency amplification follows at the 10,000 metre wave-length. This filter amplifier is similar to the first, except that the band width is only 5,000 cycles. Two additional stages of amplification can be added at this frequency if necessary. After the second amplifier the signals are again rectified and the outputs of the rectified valves work in parallel into limiting valve through a milliammeter which indicates the signal strength. The limiting valve is adjusted to give about 3-4 milliamps of plate current when the current in the plate circuit of the rectifier valve is zero. The minimum recording signal strength is that which reduces the plate current of the limiting valve to zero. Any signals of a greater intensity are dissipated in a resistance, so that the energy supplied to a direct current bridge which provides marking and spacing currents for operating the relay is constant. Means are provided for listening to the signal by superimposing an audible frequency oscillator of 1200 cycles from a valve generator on the first hetrodyne.

Land Line Circuits.—The actual operation of the services is carried out at the Central Tele-

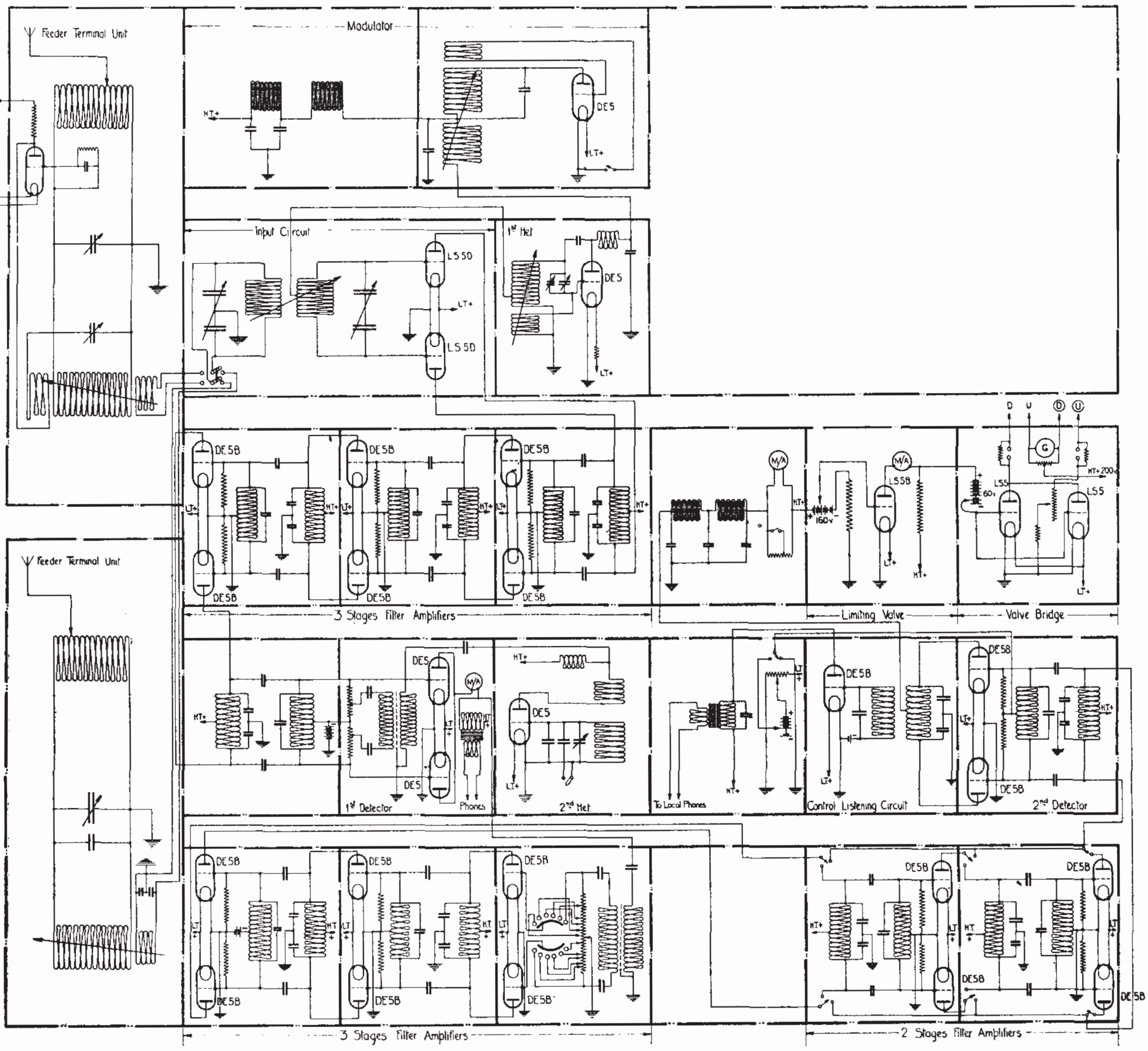


FIG. 11.—DIAGRAM OF RECEIVER.

graph Office, two Wheatstone circuits being allotted to each transmitting station and receiving station.

In addition one double current speaker is provided for each service, the transmitting Station and receiving Station being omnibus on the same line.

In order to check the land line signals at the Beam Station a Wheatstone receiver or undulator is connected in circuit on each line and constant supervision kept of the quality of the signals.

At the transmitting station a pick-up set with Wheatstone receiver is coupled to No. 1 Magnifier on each transmitter so that the signals passing to the aerial can be kept under observation.

The theoretical gain obtained from the use of Reflectors and Multiple Aerials both for the transmitting and receiving stations as employed in the "Beam" System is beyond the scope of this article. It involves the consideration of the intensity of field in the horizontal plane, *i.e.*, the polar diagram in that plane, and also the angle of propagation in the vertical plane.

In the specification governing the Beam Stations the only stipulations were that "the aerial systems to be so designed as to concentrate the emitted waves within an angle of 15° on either side of the axis of transmission; the energy of the radiations beyond this angle not to exceed 5% of those on the axis; the receiving stations to have a similar aerial system designed to have its maximum receiving power in the direction of the desired stations."

In this connection, Fig. **12** is of interest as indicating the field strengths which were measured at Bodmin at a distance of 6217 ft. from the centre of the system with the original aerials operating on a wave-length of 26.086 metres.

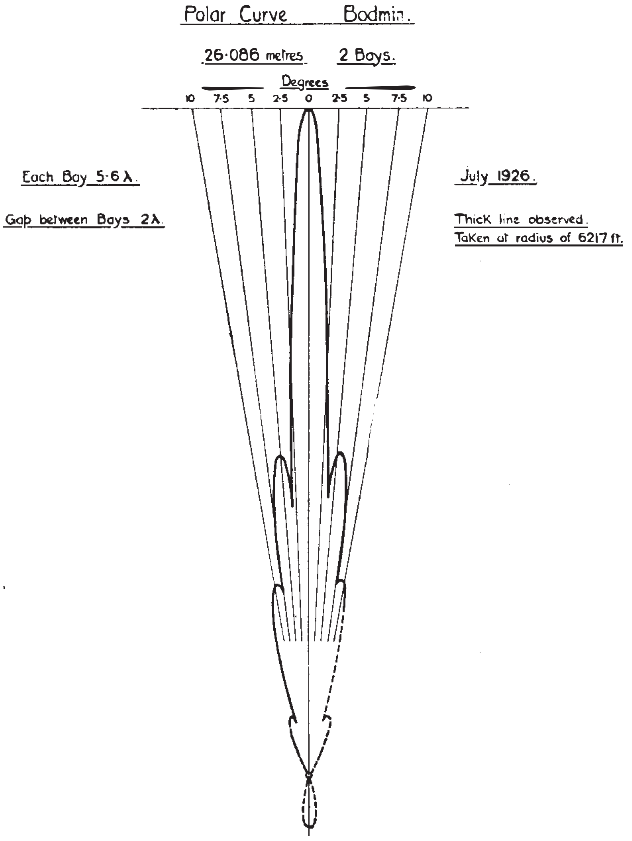


FIG. **12**.—BODMIN POLAR CURVES.

In addition to the gain obtained by concentrating the energy in the required direction from the transmitter, the use of the beam aerial system for the receiver has other apparent advantages. The signal strength is increased proportionately to the wave front intercepted by the aerials and to the reinforcement from the reflectors, whilst the effects of fading, so pronounced at certain periods on short waves, is minimised to some extent.

The successful introduction of the Short-Wave Beam System over long distances and on a commercial basis has been an undertaking of a pioneer nature and of such far-reaching consequences as to reflect great credit on the initiative and enterprise of the Marconi Coy.

The inauguration of the Empiradio service between this country and the Dominions has been followed by the adoption of short-wave directive system on the "beam" principle by many other countries, and has undoubtedly marked a great advance in the art of long distance communication.

The photographs and drawings illustrating this article have been supplied by the courtesy of Marconi's Wireless Telegraph Coy., Ltd., to whom generous acknowledgement is made.

A.S.A.

SEAFORTH RADIO STATION

CONVERSION OF SPARK TRANSMITTER TO CONTINUOUS WAVE AND INTERRUPTED CONTINUOUS WAVE TRANSMITTER.

W. M. OSBORN, A.M.I.E.E.

AN important event in the history of the British Coast Radio Stations took place on the 16th August last, when the system of transmission by Interrupted Continuous Waves was brought into use at Seaforth Radio Station in place of the Spark system, which has been the system in general use for normal ship and shore communication since the inception of the service.

This innovation initiated a scheme, foreshadowed in an article by Mr. E. H. Shaughnessy on the "Post Office Wireless Services" which appeared in Volume 19, Part 1, of this Journal, for the equipment of the British Coast Radio Stations with Valve Transmitters in anticipation of the probability, which has since been realised, that the next International Radiotelegraph Conference would prohibit the use of Spark in favour of the Interrupted Continuous Wave system. The International Radiotelegraph Conference held at Washington, U.S.A., in October last agreed, subject to ratification by the Governments represented, to prohibit the use of the Spark system by land stations after January 1st, 1935, and by ship and all other stations after January 1st, 1940, except stations using less than 300 watts primary power.

The Interrupted Continuous Wave system is the equivalent of the Spark system in so far that both systems employ types of emissions which can be received on a crystal receiver or on an ordinary valve receiver without a heterodyne. Interrupted Continuous Wave transmission causes much less interference to broadcast and other services than Spark transmission; this is due to the sharper resonance curve obtained with the former as compared with the latter transmission.

It was considered desirable to gain some experience of the suitability of Valve Transmitters for the operating and range requirements of the Coast Station Service before proceeding with the general replacement of the Spark Transmitters at the Coast Stations; the Seaforth Station was selected for this purpose in view of the small amount of structural alterations required to accommodate the new plant and also on account of the desirability of minimising the interference to broadcast reception experienced in the thickly populated area around Liverpool. The Seaforth Station is situated only 4 miles, approximately, from the centre of Liverpool.

The Spark Transmitter at Seaforth Radio Station was a 1½ K.W. Set of the Radio Communication Coy.'s standard type and was installed by the Company in 1922. A contract based upon a specification prepared in the Post Office Engineering Department was placed with the Radio Communication Coy. for the conversion of the Spark Transmitter to a Valve Transmitter adapted for Continuous Wave and Interrupted Continuous Wave telegraphy. The contract provided for the utilisation, as far as possible, of the existing apparatus and for the work to be carried out without interruption to the activities of the station.

Provision has been made for Continuous Wave and Interrupted Continuous Wave equipment in anticipation that the Continuous Wave system will at some time be utilised for some purposes in ship and shore communication; the Interrupted Continuous Wave system may ultimately be reserved for calling and distress purposes.

General Description. — The new equipment comprises Main 1½ K.W. and Emergency 100 watt coupled circuit Valve Transmitters. The Main Transmitter is equipped for operation on 220, 600 and 800 metre waves and, in addition, provision is made for continous change of waves between 780 and 820 metres. The changes in wave and variations in power are effected from the operator's position by a Bowden wire system of remote control. The Emergency Transmitter is equipped for operation on a 600 metre wave only.

For Interrupted Continuous Wave transmission both Transmitters are designed for a note frequency of 1000 per second.

The main aerial of "umbrella" type, supported by a mast 150 feet high, is used for the 600/820 metres wave range. The insulation of this aerial was improved, prior to the conversion of the transmitter, by the replacement of the old type rubber strop insulators by porcelain rod insulators; this was desirable in view of the high standard of aerial insulation required for satisfactory valve transmission. For the 220 metres transmission a separate aerial consisting of a single wire, approximately 80 feet in length suspended from a pole 80 feet high, has been provided.

Power for operating the Main Transmitter is taken from the 460 volts D.C. public supply service; the Emergency Transmitter is arranged for operation from a battery of secondary cells, to ensure that the station shall not be completely out of action if the power supply service fails or for other similar reason.

Lay-out. — The duplicate motor-alternators, main transformer and power panel which formed part of the Spark installation have been retained. The motor-alternators and a motor-generator for the Emergency Transmitter are accommodated in the Machine Room adjoining the Operating Room; the power panel and the transmitting plant are installed in the Operating Room. The Transmitters are assembled behind a protecting lattice screen on an apparatus bench near the operator's position; the indicating instruments associated with the Transmitters are under the operator's observation and all control of the plant is effected from the operator's position.

Control.—Bowden wire controls working over a system of pulleys are provided for switching over either aerial to the Main or Emergency Transmitters and for wave changing. The change-over from Continuous Wave to Interrupted Continuous Wave and *vice versa* with either Transmitter is effected by hand-operated switches; an automatic starter with press button control for the motor-alternators and a hand-operated switch for the control of the emergency motor-generator are provided, and the change-over of the aerial in use from the Transmitter to the Receiver is also effected electrically by a switch at the operator's position.

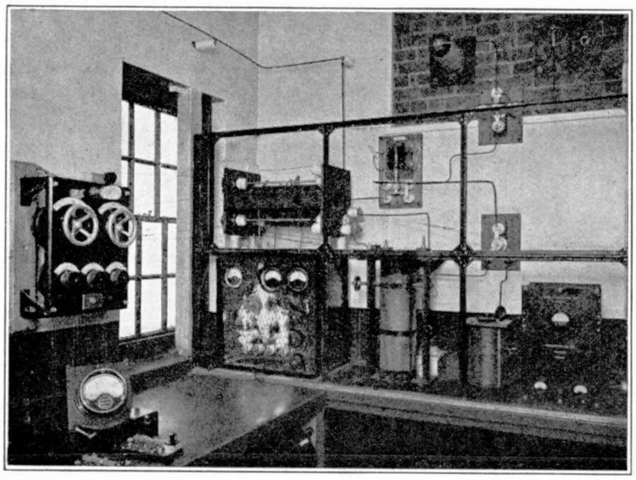


Fig. 1.—Seaforth Radio Station.

The Transmitters operate in conjunction with the Station's Valve Receiving plant and are associated with that plant by means of a "Send-Receive" switch which provides for the isolation and protection of the Receiver from the Transmitter when the latter is in operation.

Fig. **1** is a photograph of the new transmitting equipment as installed at Seaforth with the protecting screen removed and without the power panel. The Bowden wire control panel can be seen mounted on the wall over the operating bench on the extreme left of Fig. **1**; the Main Transmitter is shown on the left and the Emergency Transmitter on the right assembled with their component parts on the apparatus bench; the leading-in insulators and the switching accessories can be seen mounted on the wall over the apparatus bench.

The two transmitting keys shown in Fig. **1** on the left of the operating bench are associated with the Main and Emergency Transmitters respectively. The ammeter shown immediately behind the transmitting keys indicates the aerial current for both Transmitters, and is of the moving coil type shunted across a thermo-junction in the aerial circuit.

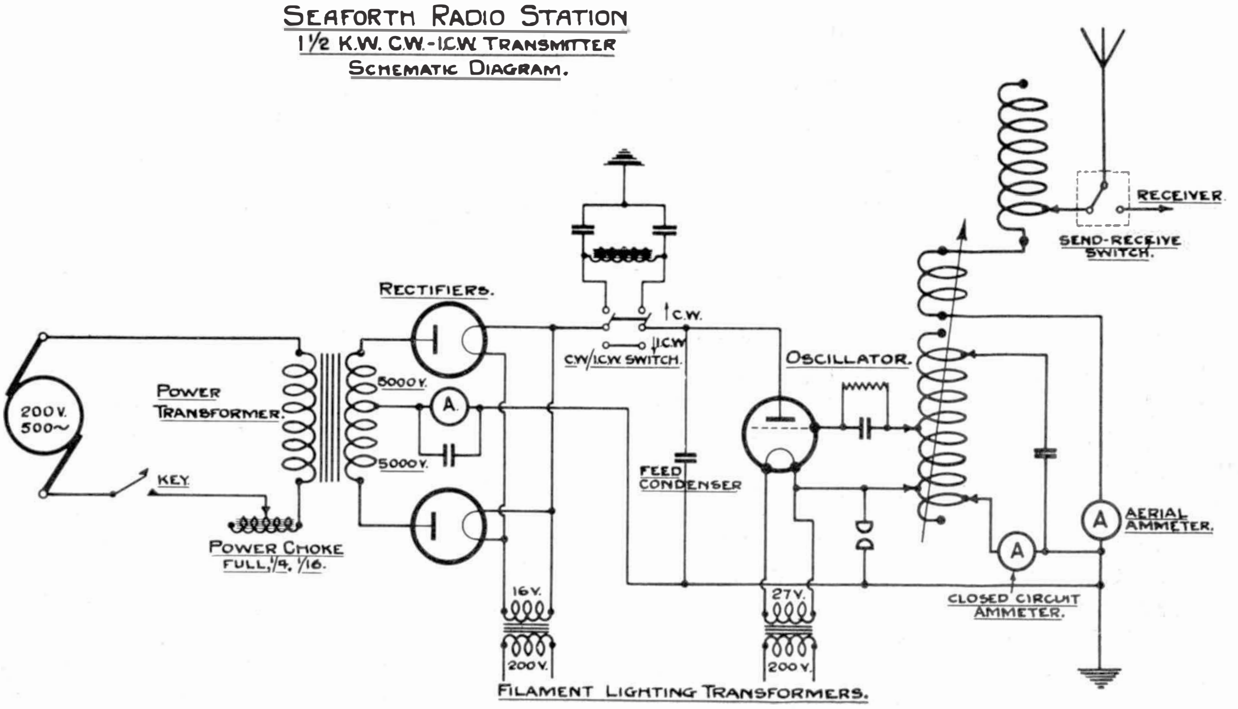


Fig. 2.

Figs. **2** and **3**, respectively, are schematic diagrams of connections of the Main and Emergency Transmitters.

Main Transmitter.—The Main Transmitter is of the Radio Communication Coy.'s standard type modified to meet the Post Office specification requirements.

The Transmitter consists of an angle iron structure with enclosing side panels and a hinged front gate, which is fitted with a safety switch so that the H.T. transformer circuit is broken when the gate is open.

The 5000 volts H.T.D.C. supply for the oscillating valve is obtained from a motor-alternator and transformer associated with rectifying valves as indicated in Fig. **2**. The motor-alternators are rated for an output of 1½ K.W. at 200 volts at a periodicity of 500 cycles per second. The rectifying unit employing two glass valves rated at 150 watts anode dissipation is of standard "full-wave" type, thus producing a ripple in the H.T.D.C. supply at a frequency of 1000 cycles per second.

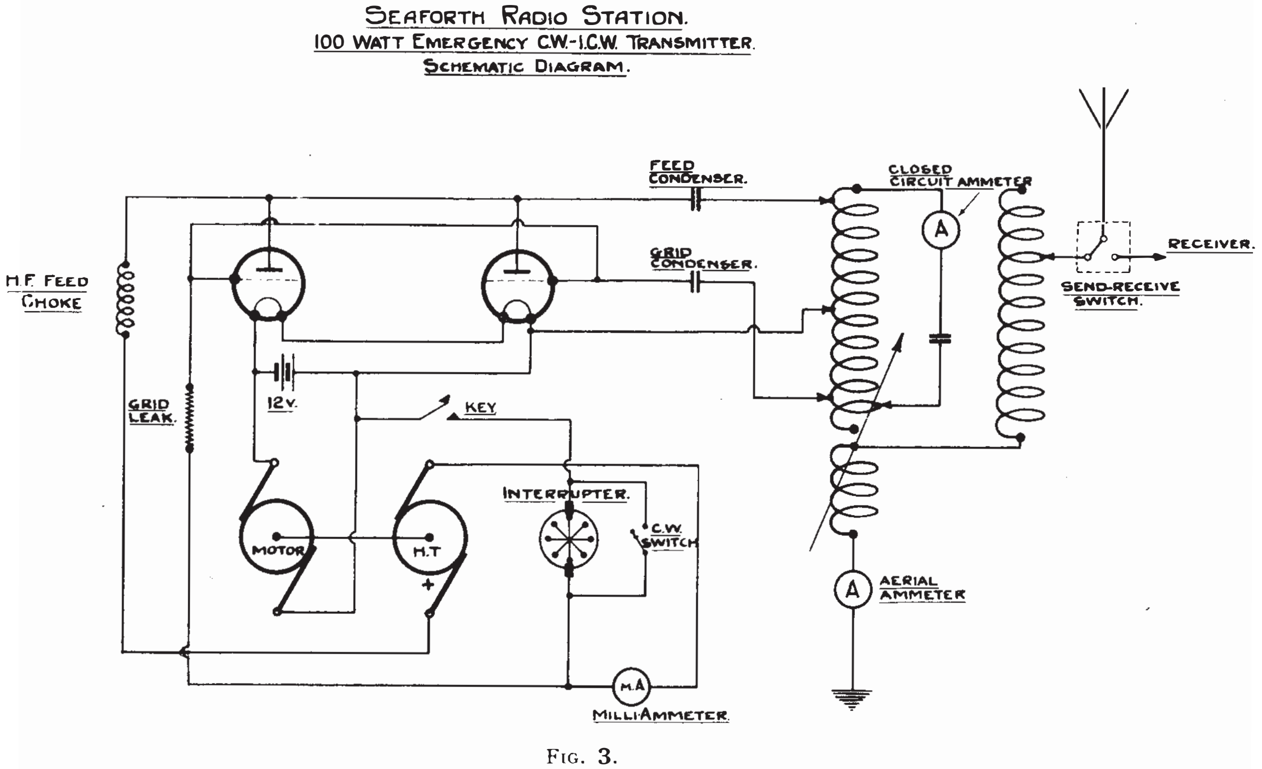


FIG. **3**.

The rectified H.T. supply is smoothed for continuous wave transmission by means of choke and condenser units; for interrupted continuous wave transmission the smoothing unit is disconnected, when the waves generated by the oscillating valve are modulated at the frequency of the rectified H.T. supply, viz., 1000 per second, which is the emitted note frequency of the Interruped Continuous Wave Transmitter.

The oscillating valve is of glass type rated at 300 watts anode dissipation.

The filaments of the oscillating and rectifying valves are heated by the 200 volts A.C. supply transformed down to the required filament voltages. Variable chokes for regulating the brilliancy of the oscillator and rectifier filaments and an adjustable compensating choke for the purpose of maintaining the brilliancy of the filaments during the intermittent keying load are included in the primary circuit of the transformer; for simplification, these chokes are not shown in Fig. **2**.

The oscillating valve is associated with a closed oscillatory circuit loosely coupled to the aerial circuit.

The closed circuit and aerial tuning inductances are of plated copper strip wound edgewise on grooved insulating supports to which connections and wave-change tappings are made by spring clips. Variometers are included in the closed and aerial circuits for continuous wave change between 780 and 820 metres.

The condensers enbodied in the Transmitter are of the mica di-electric type.

From Fig. **2** it will be seen that the signalling key and a power switch regulable to 1/16, ¼ and full power are included in the main transformer primary circuit; the power switch is provided to facilitate compliance with the Operating Regulation calling for the use of minimum power for effective communication.

Emergency Transmitter.—The Emergency Transmitter is a self-contained unit of the panel type and is designed to operate with a total power input of 100 watts from a 12 volt battery of secondary cells of 120 ampere-hour capacity.

From Fig. **3** it will be seen that two valves are employed with their filaments in series and that the battery supplies current for the filaments and also for the motor-generator which supplies the H.T.D.C. power to the anodes of the valves.

The motor-generator is designed for an input of 80 watts and an output of approximately 40 milli-amperes at 1000 volts D.C.

The Transmitter employs two glass valves as oscillators, connected in parallel; the valves are of the dull emitter type capable of dissipating 40 watts at the anodes.

The circuit employed is that of the well known Hartley oscillatory circuit associated with a coupled circuit.

For Interrupted Continuous Wave transmission, the valve oscillations are interrupted by making and breaking the grid and anode circuits at audible frequency by means of a rotary interrupter mounted on the shaft of the motor-generator and revolving at the same speed as that machine. In operation, the oscillations generated by the valves are interrupted at a frequency determined by the speed of the motor-generator and the number of insulating segments in the rotary interrupter.

For Continuous Wave transmission the brushes of the interrupter are short-circuited by a switch.

Test Results. — The valve equipment has proved eminently satisfactory as regards reliability, facility of operation and transmission range; experience has shown that 1/16 power is sufficient for the major portion of the traffic requirements of the Station.

On test, the flank Stations at Portpatrick and Fishguard reported a definite increase in signal strength over the old Spark signals, and it is generally agreed by other Stations that the Interrupted Continuous Wave transmission is very sharply tuned and that the note is clear and steady. With 1/16 power in use satisfactory tests with crystal reception have been obtained at sea ranges of over 150 miles from Seaforth.

Opinions from reliable sources are generally in agreement that a definite diminution in the interference to broadcast reception has resulted from the change-over from Spark to Interrupted Continuous Wave transmission at the Seaforth Station, especially in the case of receiving stations situated within one mile of the Station. In this connection it is of interest to note that Wireless Operators in vessels approaching the Port of Liverpool could formerly listen-in to the Liverpool Broadcast Station's programmes (6LV, 297 metres) and at the same time receive Seaforth's Spark signals on 600 metres, but since the change-over the closer tuning required for the reception of the Interrupted Continuous Wave transmission renders impossible the simultaneous reception of Seaforth's signals and the Liverpool broadcast.

Development.—Following on the successful installation of the Valve Transmitter at Seaforth Radio Station, arrangements are in train for the general adoption of this type of Transmitter at all other Coast Radio Stations in place of the existing Spark Transmitters. This reorganisation scheme will provide for 1½ K.W. Transmitters at the Niton (Isle of Wight), Fishguard, Portpatrick, Cullercoats and North Foreland Stations, a 3 K.W. Transmitter at the Wick Station and, probably, two 6 K.W. Transmitters at the Land's End Station.

Provision will be made for flank Coast Stations to have different note frequencies to avoid the possibility of confusion which might occur to ships stations receiving signals of equal strength from two Coast Stations having notes of the same characteristic and frequency.

The installation of the new plant will involve the re-modelling of the Station buildings. The North Foreland Station is to be removed to a new site at St. Peters, Broadstairs, and at Cullercoats a new building is to be erected on the existing site.

The " Humber " Radio Station at Grimsby was removed to a new site at Mablethorpe on the 6th December last; the new Station is equipped with a 1½ K.W. Transmitter of similar pattern to that installed at Seaforth. It is hoped to give a descripion of the new " Humber " Station in a future issue of this Journal.

It is interesting to recall that the last comprehensive re-organisation of the Coast Radio Stations took place over 15 years ago and was described in an article by Messrs. E. S. Perrin and F. W. Davey, published in Volume 6, Part 4 (Jan., 1914), of this Journal.

NEW DISCOVERIES, NEW TOOLS, NEW PROBLEMS.

A BRIEF REVIEW OF SOME OF THE RECENT ADVANCES IN PHYSICS.

W. G. Radley, B.Sc. (Hons.), A.M.I.E.E.

New Discoveries.

By the year 1895 a certain degree of completeness had been given to the edifice of physics. A perfectly satisfactory explanation had been found for the great majority of phenomena which had been observed in the laboratory. Following on the experiments of Faraday, Maxwell had developed a theory of light which, by presenting a value for the speed of the imagined electromagnetic waves determined exclusively from measurements upon magnetic and electric fields, had united at one swift stroke two hitherto separate branches of physics. Newton's old corpuscular theory of radiation seemed to have passed finally into the limbo of forgotten things. As far as we could see, everything was in order. But our vision was limited by the microscope. And in that same year Rontgen, looking for some form of radiation which should have a greater power of penetration than visible light, discovered X-rays. A year later and Henri Becquerel had made the discovery of the curious property of radio-activity in uranium and its compounds.

The tools which these two discoveries put into the hands of modern scientists have led to great and amazing advances in our knowledge of matter. And very much of the new knowledge—both of matter and of radiation—has proved to be incapable of explanation in terms of the old familiar theories. Ideas have had to be revised. In more ways than one, new facts which have come to light have necessitated a revolutionary change in outlook.

During the same period immense technical advances in the art of communication—the application of the thermionic valve to both cable and radio circuits to take only one example—have absorbed the full attention of the telephone engineer, and have left him little opportunity to keep abreast of those rapid developments in pure science on which the whole art of engineering is ultimately based. Perhaps, therefore, a very brief sketch of the broad outlines of modern development may be of interest to readers.

New Tools.

(i) *The X-ray Method.* The principal significance of Rontgen's discovery lay in the fact that it was to provide a means of vision which should enable us to see greater detail in the structure of matter. During the lapse of more than two hundred years that had passed since its invention, the compound microscope had been perfected almost up to its theoretical limit. This is such that, using ordinary light, we can never hope to distinguish by its aid the shape of a body much smaller than a wave length of light, *i.e.,* about .0005 millimetre. The wave-length of the rays emitted by an X-ray tube with a tungsten target are approximately 1/5000 of this, that is, of the same order as the size of atoms. An X-ray microscope is not yet available; but suppose a piece of material to be irradiated by a beam of X-rays. Each atom will act as a scattering centre for the X-ray waves falling upon it. We cannot detect the waves scattered by a single atom. However, if there is any regularity about the arrangement of the atoms throughout the body of the material, along certain directions for rays of one definite wave length waves scattered by a large number of atoms will be in phase with one another. They will then reinforce each other and produce a reflected ray of such intensity that it can be detected on a photographic plate. The principle is exactly the same as that employed by the experimenter with visible light, when by means of a closely ruled grating he splits up a beam of light into its spectral colours. If now, instead of employing a heterogeneous beam of X-rays of all wave lengths, we arrange that the beam shall contain rays of one wave length only (λ), reflection will not take place unless certain critical relationships are fulfilled. These are such that, if the atoms be arranged on a regular series of planes distant d apart, both incident and reflected rays must make with these planes an angle θ which satisfies the equation,

$$n\lambda = 2d \sin \theta \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

n being any whole number.

This at once gives us a means by which we are able to interpret the arrangement of groups of atoms traversed by a beam of X-rays, almost as exactly as if we had an X-ray microscope. Instead of guessing the internal arrangement of its atoms from the outward form assumed by a crystal, we find ourselves able to measure the actual distance from atom to atom.

The original experiments were made at Munich by v Laue seventeen years after the first discovery of X-rays. Very much of the subsequent development of the method is due to Sir William and W. H. Bragg. This method of analysis has proved to be wonderfully useful. Not only can it be applied when the material is in the form of a single crystal; it yields results whenever there is the slightest regularity about the structural arrangement, even if each separate element of regularity is ultra-microscopic in size. Fig. **1**, for example, is a reproduction of an X-ray spectrogram taken in the Research Section from carbon granules out of a telephone transmitter. Contrary to time-honoured ideas this carbon is not strictly amorphous, that is, without the elements of a crystalline structure. The fact that X-rays of one wave-length were reflected from it more strongly at certain angles than at others reveals that it has a definite structural pattern. And this pattern is the same as that of graphite, because the angles at which reflection occurs are the same for the two materials. The result obtained when graphite is substituted for the carbon granules is shown in Fig. **2**. It will be seen that the reflections correspond, though the pattern obtained on Fig. **1** is very much more ill-defined, and only just beginning to appear as it were. This is explained very perfectly by the fact that the homogeneous fragments of graphite crystal in the amorphous granules are still exceedingly minute.

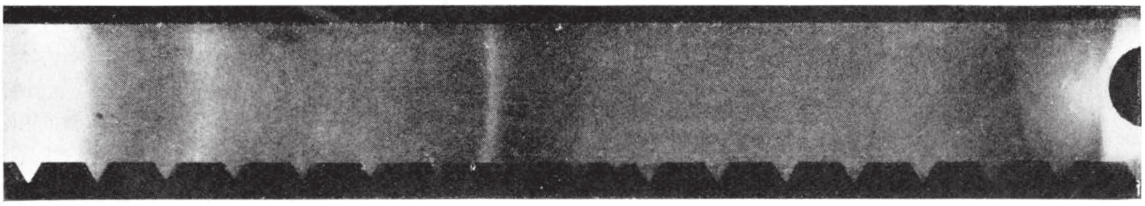


FIG. 1.

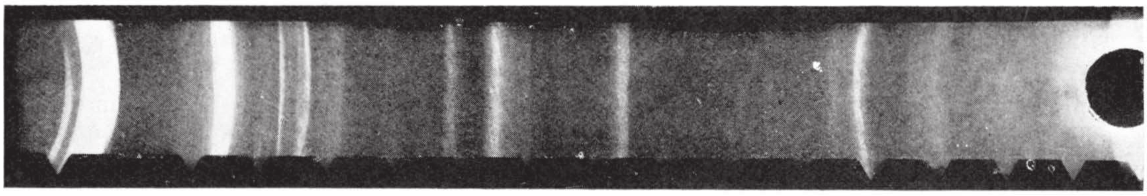
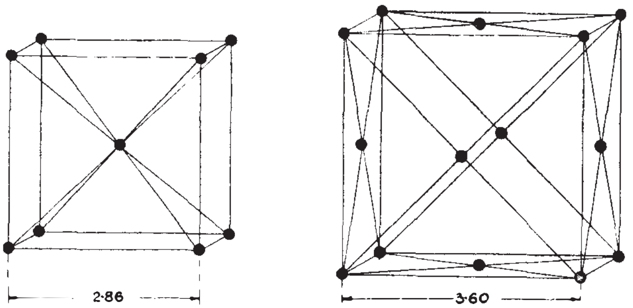


FIG. 2

To the metallurgist the method of X-ray analysis is invaluable. Deformation of the structural arrangement due to too vigorous cold-rolling or stressing, fibreing, or the effect of annealing in causing growth of the little elements of regularity —all are revealed. It enables him to follow an atomic re-arrangement taking place within a metal as its temperature is raised. For instance, in a series of experiments Westgren found that for an iron wire at ordinary temperatures the arrangement of the atoms was as in Fig. **3**. He heated the wire to a temperature just over 900°C, and the atoms re-arranged themselves according to Fig. **4**. Iron, when heated to a high temperature, becomes non-magnetic. But we have not by chance stumbled on the secret of ferro-magnetism. The change in atomic structure cannot be made to explain the loss in magnetic properties. One does not take place until 200° C after the other with pure iron. Besides, although iron at normal temperatures regularly crystallises according to the pattern shown in Fig. **3**, nickel and cobalt, the other two strongly magnetic elements, are magnetic when found in the pattern shown in Fig. **4**. At the most, both changes which occur when the iron wire is heated can only be the result of internal changes taking place within the atom itself.



Dimensions in Ångstrom Units : 1 Ångstrom Unit = 10^{-8} cm.

FIGS. **3** AND **4**.

(ii) *The use of Alpha particles.* The interior of the atom has not been nearly so completely explored. Indeed, had it not been for Becquerel's discovery of the radio-active elements, the interior might have remained completely unknown right up to the present day, for radio-active elements are the source of alpha particles. And a vast amount of theory about the internal structure of the atom rests solely on the evidence of experiments which have been conducted with the aid of these fast flying particles. It is as if the advance guard of an army of discoverers having arrived at last before the walls of the atomic citadel Nature had handed out to them just the projectiles needed to batter down those walls and disclose what was inside.

It was thought at first that the effect produced by radioactive compounds on a photographic plate held near them was due to their emitting some new kind of ray. They were firing off something of even greater value—positively electrified particles of matter with an initial velocity of over 10^9 cms. per second. Later, the mass of one of these particles was found to be equal to that of the helium atom, the electrostatic charge carried by it to $+2e$.* Losing an alpha particle, a radio-active atom transmutes itself into an atom of the element lying two places further down the periodic table. Each atom of radium gives up five of these alpha particles before it finally appears as lead; but so enormous is the velocity with which they are fired off that a single one of them is capable of producing a distinct scintillation when it hits a phosphorescent screen.

When alpha particles are fired into a gas, each one of them leaves behind it a trail of ionised atoms. If this takes place in a supersaturated atmosphere each ion formed will become the centre of a minute drop of water; so that when they are illuminated a photograph can be obtained of the track of the alpha-particle. Striking photographs taken in this way show that the tracks of the great majority of the alpha particles are perfectly straight from beginning to end; but an occasional one will show an abrupt change of direction, just as if the flying particle had come into collision with some heavy mass. Not only will the alpha particle ordinarily take an undeviating course through hundreds of thousands of gas molecules, but more remarkable still, it will pass through thin sheets of metal foil. There is obviously only a very small part of each atom which is impenetrable to these swiftly flying particles. The original experiments of Sir Ernest Rutherford along these lines established the amazing fact that the interior of the atom was mostly empty space.

The fact that a certain proportion of the alpha particles which fell upon the metal foil were scattered through definite angles gave Rutherford some evidence of the size of the impenetrable nucleus. His latest estimate of the diameter of the nucleus of the lighter atoms is approximately 5×10^{-13} cms. When we remember that the diameter of most atoms is round about 10^{-8} cms., or 20,000 times the diameter of the nucleus, the amazing emptiness of the atom at once becomes apparent.

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* *$e = 4{\cdot}774 \times 10^{-10}$ absolute electrostatic units.*

The nucleus is positively charged. That this positive charge, measured as a multiple of the natural unit charge, "is the same as the number of the place occupied by the element in the periodic table" was Moseley's splendid idea. It had been known for some time that the wave-length of X-rays should be of the order of 10^{-8} or 10^{-9} cms. To construct a ruled grating with a spacing suitable for the measurement of such tiny wave-lengths was unthinkable. But it had just been shown that the regular spacing of the atoms in a crystal would act as such a grating—as we have already seen. This enabled Moseley to measure the wave-length of the lines in the X-ray spectra of a large number of the elements. The simplicity and regularity of the steps, as he went from one element to the next, gave him invaluable evidence of the correctness of his theory. A great amount of subsequent work in every direction has gone to strengthen that theory. Under its guidance all the elements have fallen into an ordered procession which, extending from hydrogen with unit nuclear charge to uranium with a nuclear charge of ninety-two units, has now remaining only two vacant places. These correspond to the atomic numbers of 85 and 87. The atomic number has become of more fundamental importance than the atomic weight of the chemists. It specifies the positive charge on the nucleus, and the nuclear charge determines all the chemical and electrodynamical properties of the atom.

Curiously enough, Aston has recently shown that, expressed on the scale on which the atomic weight of oxygen is 16, the atomic weights of practically all the elements are whole numbers. The existence of an apparently fractional atomic weight, such as that of chlorine (35.46), is explained by the fact that this gas is in reality a mixture of two isotopes, each having a nuclear charge of 17 units and exactly identical in chemical properties but having atomic weights of 35 and 37. All chemical methods, such as those employing diffusion, entirely fail to separate these two isotopes. Aston's method was to cause ionised atoms of chlorine to pass successively through an electric and a magnetic field. Each of these fields deflects the flying atoms, the deflection given to each atom depending on its mass and also on the nett electrostatic charge carried by it. In this way atoms with a mass of 35 can be made to strike a photographic plate at a different point from those carrying the same charge but with a mass of 37. Aston's achievement was not to measure the mean atomic weight of a mixture of thousands of millions of atoms. His apparatus recorded the weight of individual atoms.

In the neutral atom of atomic number Z, the total positive charge on the central nucleus (Ze) is balanced by Z electrons each carrying a negative charge equal to $-e$. The existence of these electrons has been known experimentally since just before the beginning of the present century. Sir J. J. Thomson was their discoverer. He first observed their presence in a tube filled with a rarefied gas through which an electric discharge was being passed. It has since been shown that they can be coaxed out of all matter. They must therefore form a universal ingredient to every atom made up by Nature. This is revealed by experiment.

An individual electron can be captured on a droplet of oil, or on a minute solid particle, and the amount of its charge determined. Millikan, as a result of a series of most delicate measurements, gives this amount as 4.774×10^{-10} electrostatic units. It never varies. It is the natural unit of charge, and by convention is always denoted by the letter e. When a magnetic field is applied to a stream of electrons all moving with the same speed, the electrons are all deflected to the same degree, which shows that they all have the same mass. This is practically equal to 9×10^{-28} grammes, which is about $\frac{1}{1840}$ of the mass of the hydrogen atom—the lightest atom known.

It would take about one thousand million million iron atoms to make up a grain of dust just visible to the naked eye. If we were to construct a scale model of one of those iron atoms as big as the dome of St. Paul's Cathedral, we should still have some difficulty in finding the 26 electrons which are disposed somehow in the empty space about the nucleus. They would still be scarcely as large as pin-heads. The capture of one of those electrons and the accurate measurement of its charge and mass has been one of the most brilliant achievements of twentieth century science.

NEW PROBLEMS.

The existence of the electron is a definitely proved experimental fact; its mass and charge are known with a high degree of accuracy. So, too, has experiment more or less definitely established the fact that the space occupied by the atom is almost entirely empty. The disposition of the electrons within that empty atomic interior is a problem which has given a considerable amount of trouble to physicists. Even now all is still conjecture. It is comparatively easy to fire alpha particles through atoms and prove that they are mostly empty inside, or even to tear atoms to pieces in an electric discharge and so discover their constituent parts. It is when an attempt is made to fit the parts together again that the dispute arises. What is needed is not merely an advance in present technique, but another discovery opening up completely new ground, as did that of Laue. And the principle of the new discovery must be that of an ultra X-ray microscope—possibly one working on a high speed cinematograph principle that will not only reveal to us the exact positions of nucleus and electrons, but also their relative motions.

For it seems highly probable that the electrons are in rapid rotation round the nucleus. They cannot readily be imagined to be at rest. If they were, the force of attraction between unlike electric charges would rapidly cause the tiny negative electrons to fall into the more massive positive nucleus. Of course, we may assume that at the very small distances which exist within the atom the ordinary laws of electrostatic attraction and repulsion no longer hold. But many experiments, such as those performed by Rutherford, tend to the conclusion that at distances very much less indeed than the diameter of the atom the inverse square law of repulsion is perfectly valid. More acceptable is the idea that the electrons rotate, and that the force of attraction which would draw them inwards is just balanced by centrifugal force acting outwards. Indeed, the idea of a very minute sun and planets system —the nucleus, a sun around which the electrons planet-like run their courses—is very alluring. Unfortunately, the laws of electromagnetic radiation forbid it. According to these laws radiation of energy continually goes on from an accelerated electrified particle; and how then is the electron to continue giving out energy without slowly depleting its own store and spiralling its way to rest in the nucleus? If he is left with no more than the classical ideas of radiation to help him, the dilemma of the physicist is complete.

Here it becomes necessary to say a few words about that same subject of radiation; but only to point out that the idea that light consists of a wave motion is not sufficient to explain all the phenomena that are known of it to-day. In the year 1900 Planck published the results of his researches on the character of the radiation within an enclosed cavity. His results could not be explained in terms of the wave theory. They were entirely foreign to it. It was as if radiant energy of any frequency ν were concentrated into little packets, or units, of magnitude $h\nu$, h being a constant; and that these little packets were emitted, journeyed through space and were absorbed entire. Such was Planck's suggestion. It had nothing to recommend it to a generation of scientists who had witnessed a series of beautiful and striking experiments founded on the wave theory as their basis. It has nothing to recommend it to-day, except the fact that it is apparently true. For it is the only explanation there is to offer for an ever increasing number of phenomena, which range from the law of action of the feebly illuminated photo-electric cell to the peculiar character of the emission from the target of an X-ray tube bombarded with electrons at tens of thousands of volts. Disguised as fast flying quanta Newton's light-bearing corpuscles have made their re-appearance. But the new quantum theory involves the wave theory at its root; for the magnitude of the little packet of energy which is shot through space is h multiplied by its frequency, and the frequency is the speed of light divided by a wave-length. Thus have the two prevailing ideas of radiation, so apparently contradictory the one to the other, become inextricably interwoven.

This little digression on radiation is justified by the fact that there is something very characteristic about the radiation given out by excited atoms. It is restricted to certain definite frequencies, giving the familiar series of bright lines in the spectrum. And it does not matter whether this radiation has its source in the experimenter's laboratory or is flashed across millions of miles of space from the stars, the intricate pattern of glowing spectral lines peculiar to any particular element remains unaltered. For many of the elements these lines have been found to fall into groups. And sometimes a very simple numerical law can be found connecting together all the lines in a group. Balmer measured the wave-length of a number of lines in the spectrum of hydrogen, and found that the frequency of the radiation corresponding to each of these lines could be expressed by the formula :—

$$\nu = R\left(\frac{1}{n_1^2} - \frac{1}{n^2}\right) \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where n_1 equals 2, and n is given one of the whole number values 3, 4, 5, 6 . . . etc., R being a constant.

Is it possible that the whole secret of the arrangement of the nucleus and the electrons within the atom may be revealed through an intricate pattern of spectral lines recorded on a photographic plate? It seems very probable. For the whole of our modern ideas of atomic architecture—of microcosmic solar systems in which each electron traces out a definitely assigned orbit—dates from 1913, when Nihls Bohr, of Copenhagen, discovered a way of interpreting spectra.

Bohr's interpretation was based on three assumptions. They were :—

(i) That within the atom electrons can circulate in closed orbits *without radiating energy at all.*

(ii) That an electron can only circulate in a limited number of orbits permitted by certain conditions. The condition usually quoted is that the orbit must be such that the angular momentum of the electron in it is an integer multiple of $\frac{h}{2\pi}$. Thus for a given atomic system, a series of energy values E_1, E_2, E_3 . . . alone is possible, each energy value corresponding to one of the permitted orbits.

(iii) That when an electron jumps from an orbit in which the energy value of the system is E to another in which the energy is E_1, E_1 being less than E, it radiates an amount of energy equal to $E - E_1$; and the frequency of the radiation is given by :—

$$h\nu = E - E_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

These were Bohr's assumptions. The fact that the model of the atom, which he has constructed on them, has proved remarkably successful in a certain limited field has caused them to be widely accepted. But, if anyone could think of a reasonable explanation why an electron should only be able to rotate in certain orbits and not in others, or why, for that matter, it should be able to rotate at all without radiating energy, the present day atom model would be immensely fortified.

Let us look for a moment at the model constructed by Bohr for the atom of hydrogen (Fig. **5**). Hydrogen is the first element in the periodic table. Its nucleus carries a positive charge of one unit, so that one electron only is needed to complete the atom. Suppose that this electron, of mass m and charge $-e$, is rotating with a velocity v in a circular orbit of radius r. The kinetic energy of the electron is $\frac{1}{2}mv^2$. Reckoning the potential energy of the electron when it is

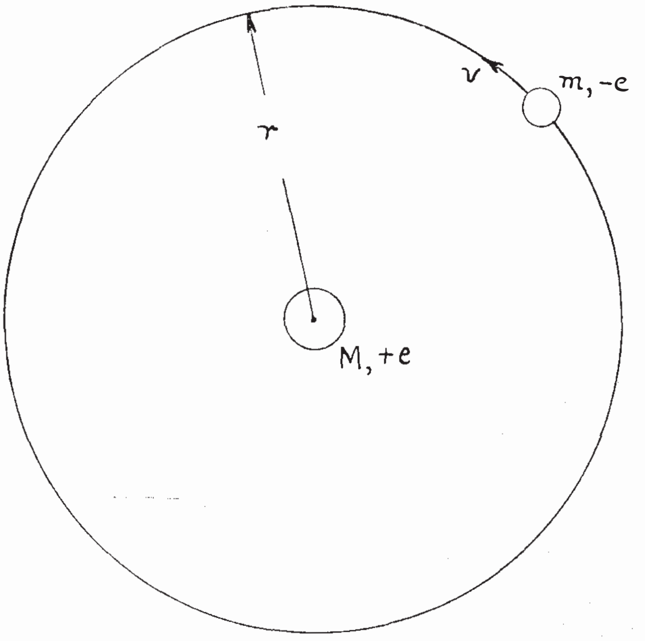

FIG. **5**.

completely removed from the atom as zero, its potential energy when it is at a distance r from the nucleus is equal to $-\frac{e^2}{r}$. Therefore the total energy (E) is given by :—

$$E = -\frac{e^2}{r} + \tfrac{1}{2}mv^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

By equating the centrifugal force to the electrostatic attraction we have,

$$\frac{e^2}{r^2} = \frac{mv^2}{r} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

so that,

$$E = -\frac{e^2}{2r} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Again, from Bohr's second assumption the angular momentum of the electron is equal to $\frac{nh}{2\pi}$

$$\therefore\ 2\pi mvr = nh \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

where n is a whole number. It is termed the quantum number of the orbit.

With (5) and (6) equation (7) gives :—

$$E = -\frac{2\pi^2 me^4}{h^2} \cdot \frac{1}{n^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Suppose now that the electron returns from an orbit of quantum number n to another orbit, nearer the nucleus, of quantum number n_1. The difference in energy between the two states of the atom is given by :—

$$E - E_1 = \frac{2\pi^2 me^4}{h^2}\left(\frac{1}{n_1^2} - \frac{1}{n^2}\right) \ldots..(9)$$

But by Bohr's third hypothesis this difference of energy is radiated away from the atom as energy of frequency ν, where

$$h\nu = E - E_1$$

so that,

$$\nu = \frac{2\pi^2 me^4}{h^3}\left(\frac{1}{n_1^2} - \frac{1}{n^2}\right) \ldots\ldots\ldots..(10)$$

If n_1 is put equal to 2, and n to 3, 4, 5 . . . etc., a striking similarity is at once apparent between the form of this equation and Balmer's experimental formula for the frequency of the lines in the hydrogen spectrum, given at (2). But this is not all, nor the strongest evidence for Bohr's assumptions. The value of each one of the constants on the right hand side of equation (10) outside the bracket had been previously determined. If these values, for e, h, m, etc., are inserted, the new constant formed *agrees almost exactly* with Balmer's experimental constant R. Again, if n_1 is put equal to 1, 3 or 4, new series of spectral lines should be obtained. And these have actually been found. They had been overlooked because one, the Lyman series, lies right out in the ultra-violet and the other two in the infra-red part of the spectrum.

Not for all the elements will Bohr's scheme predict so simply the results to be expected from experiment. Many of the heavier atoms with whole families of electrons surrounding the nucleus have proved quite unamenable to calculation. Nor indeed does the scheme unmodified explain such phenomena as are observed, for instance, when the radiating atoms are subjected to a magnetic field. To explain these and other facts of experience mathematical theorists have elaborated and embellished the scheme, until some of their hypermysterious specifications for the atom remind one irresistibly of the recipes of the old alchemists.

But, while this strange and yet fascinating idea of Nature arranging on the smallest possible scale solar systems of the same pattern as our own big one is still unproved by direct experiment, it is as well to emphasise again what is the sum of the definite new knowledge added to our store during the past two or three decades. The electron and the nucleus have both been established as definite physical realities. Experiment has shown that the nucleus of any atom has a mass which is an integral multiple of the mass of the nucleus of the hydrogen atom. In order to build up the nucleus of any atom we need only two different kinds of bricks—protons, which are the nuclei of hydrogen atoms, and electrons. Then again much recent work on the measurement of critical potentials has shown that there exist within the atom different energy states; such as, when we turn to theory, we associate with the orbits in Bohr's model. Lastly, Planck's constant, "h," mysterious and enigmatic, has taken its place as a definite physical constant called for in the expression of physical reality, and to become as familiar in the future as is Newton's " *g* " to-day. There have been giants in the land of physics in these days.

* * * * * *

To the engineer, as well as to the physicist, the progress of discovery should be of thrilling interest. For where the experimental physicist stands to-day the engineer will probably be established to-morrow. True, the smallest piece of material which even the telephone engineer has to deal with consists of millions and millions of atoms, his smallest amount of energy to many billions of quanta. But our whole conception of the action of the photo-electric cell depends upon the new-born quantum ideas of radiation. And it seems as if the communications engineer of the future will be very profoundly interested in the action of the photo-electric cell. Again, although many of the properties which the engineer recognises in his materials, such as strength or elasticity, are not the properties of individual atoms; some, which are the electrical engineer's most vital concern, do appear to be the properties, if not of single atoms, at the most of very small groups of atoms. Magnetism is an example. We know practically nothing about the real physical nature of the change that takes place in a steel bar when it is magnetised. By alloying nickel and iron together Elmen chanced upon a material, permalloy, which in feeble magnetic fields is tremendously more magnetic than either of these metals alone. There may be other alloys which will give equally startling properties. To the metallurgist who would set out to investigate them one by one the possible number of alloys becomes absolutely overwhelming. Did we but know what it is that makes all the difference between atoms of the three succeeding elements, iron, cobalt and nickel, and those of every other element, it would perhaps be possible to prepare an alloy having any desired magnetic properties to specification. This is only one problem. By loading the conductors with a wrapping of permalloy tape we have seen the speed of an Atlantic cable increased fourfold. But the real problem of the cable—that of the dielectric—remains unsolved. And the study of the properties of matter in a feeble electric field is practically an unexplored country for the physicist.

To-day the whole realm of physics is strewn with unsolved problems. But, looking back only to the beginning of the century, one cannot but be impressed by the confidence and success with which the scientist of to-day attacks problems which then would hardly have been thought capable of solution. It is by the solution of some of these problems that revolutionary changes in the art of engineering may be brought about.

NOTES & COMMENTS

HISTORY OF THE POST OFFICE ENGINEERING DEPARTMENT.

THE Council of the Institution has had under consideration the question of arranging for the compilation of a History of the Post Office Engineering Department, but came to the conclusion that it was not possible to undertake such a task at the present time. The Council feels, however, that it would be very unfortunate if information of historical value which is at present available should be lost merely through the lack of any organisation for the collection of such valuable literary material. The Council wishes to announce, therefore, that it has decided to arrange for the filing and indexing of any memoirs or information of historical value which may be offered to the Institution.

The period in regard to which information is most valuable is that preceding the publication of the *I.P.O.E.E. Journal, i.e.,* prior to 1908.

Any document of the nature referred to which is considered of historical value, or any notes on any particular question of historical interest will be gladly received by the Secretary of the Institution, Dr. R. V. Hansford, E.-in-C.O., G.P.O. (Alder House), London, E.C.1.

THE POST OFFICE (LONDON) RAILWAY.

This tube railway, some 6½ miles long, extending from the Eastern District Post Office in the east to the Paddington District in the west, has been constructed with a view to accelerating the letter and parcel service and at the same time to relieve to some extent the street traffic congestion in the neighbourhood of the busy offices. In addition to the terminal stations, connections are made with Liverpool Street Station, King Edward Building (G.P.O.), Mount Pleasant, Western Central Office, Western District and Western District Parcel Post. It is the intention to extend the system later northwards from Mount Pleasant to the Northern District Office and to the main northern railway stations at Kings Cross, St. Pancras and Euston, while towards the south a loop line will run from King Edward Building to London Bridge Station, thence *via* the South Eastern District Office and Parcel Office to Waterloo Station and on to the South Western District Office, from which the line running north-easterly will join the main line at the Western Central Office.

The whole of the operation of the trains is automatic, starting and stopping control being effected from switch cabins at each station; no drivers are required. The rolling stock consists of steel motor wagons, made up into trains of two or three wagons, each wagon being capable of carrying a load of half a ton. The electrical equipment of the wagons consists of two 22-H.p., 440 volt D.C. series motors, in parallel, and a set of electrically operated braking equipment and reverser. The motors are energised in the usual way from the conductor rail.

Major H. C. Gunton, Principal Power Engineer, who, in conjunction with Mr. H. H. Dalrymple-Hay, Sir John Snell and Mr. A. M.

Sellar, Consultants, has been responsible for the construction and equipment of the railway, will furnish our readers with a full technical description in our July issue.

In the Journal of the Franklin Institute for December, 1927, H. Nakamoura, of the Research Laboratory, Tokyo Electric Coy., Ltd., passes " Some Criticisms on Electric Resistance and its Derivative." There are confusions, he says, between electric resistance and differential electric resistance. In one case resistance means original electric resistance and in another case it means differential resistance. In the paper he discusses distinctions between them and concludes as follows: (1) Ordinary resistance is a mere quotient of the instantaneous value of the component which is in phase with current of the potential difference of any two points to the instántanous value of the current passing through these and has no vectorial sense. Differential resistance, however, is the first partial derivative of the former with respect to the latter and has sense and magnitude. (2) Wheatstone Bridge and its varieties, unless balancing the galvanometer or telephone circuit by constant equipotential, measure the differential resistance and not the ordinary one. (3) Alternating current bridge generally measures differential effective resistance. When the current is small or its effective resistance, differential effective resistance numerically approaches to ordinary effective resistance.

The Director of the U.S. Bureau of Standards communicates interesting notes on the Seventh International Conference on Weights and Measures (held at Paris last September) in the same issue of the Franklin Institute Journal. The United States delegates were hopeful that the conference would adopt a definite relation between the yard and the wave-length of light, or between the yard and the metre. It appears that a different relation is used in this country and in the U.S.A., the difference between the British and American yard being of the order of a few millionths of an inch. Even such a small difference is of importance in the manufacture of precision tools. It was agreed that the two countries should settle the matter between them. The question of the dimensions of electrical units received considerable attention. When the international units were adopted, certain kinds of concrete standards were accepted as a means of maintaining the values of the units, such as a column of mercury of specified dimensions for the ohm and a voltameter in which the amount of silver deposited in a second by a current is used as a measure of the ampere. We now know that the international ohm is one-twentieth of 1 per cent. too large. In order to advise the international committee as to whether the old value of the ohm should be maintained or be adjusted to accord with mechanical measurements as originally intended, a special technical commission of ten members, including representatives appointed by the several national laboratories, was appointed to report by March, 1929.

Annales des Postes, Télégraphes et Téléphones, of January, 1928, contains among other interesting subjects the following articles:—

The adaptation of the French system to the universal telephonic service, by H. Milon, 22 pages.

Search for an international 5-unit Telegraph alphabet, by E. Montoriol, 7 pages.

Belt Conveyors in Central Telegraph Office, Paris, by Jean Jacob, 15 pages.

The February number contains the following articles:—

Aerial Post, by M. Lebon. Seventeen pages with three maps, showing routes of French lines in Europe, proposed routes in France and the connection of French routes with other European routes.

The choice of a single type of apparatus for the international telegraph service, by E. Montoriol, 14 pages. The author advocates the use of the Baudot system with Quadruple simplex, Triple duplex and Sextuple simplex, according to traffic needs.

The connection of underground and aerial sections of telephone lines, by Marcel Moine, 28 pages.

The characteristics of transmission on long distance cables, by Kupfmuller. (Translation from an article which appeared in the *Europaischer Fernsprechdienst* of July 5th, 1927), 33 pages.

An important article on New Preservatives for Telegraph Poles appeared in the *Telegraph and Telephone Age* of the 16th December, 1927.

The article describes the results of experiments carried out by Dr. L. P. Curtin, chemist of the Western Union Telegraph Coy. The new preservatives developed by Dr. Curtin are founded upon an entirely new theory of wood preservation, and are claimed to be more permanent in the wood than any materials previously employed. They are inorganic salts, non-volatile and insoluble as limestone. The foundation of the developments lies in the discovery that the fungous organisms most active in rotting wood evolve acidic substances. This property has been utilised to bring into solution toxic salts insoluble in water and ordinarily inert. When brought into solution by the fungous acids, the materials become fatal to the fungus. The action is the same as that of paris green, lead arsenate, etc., in poisoning insect life. Several treatments based on this discovery have been tested, the most promising being the Zinc Arsenite treatment. Zinc chloride has already been used for preserving purposes and arsenic has long been employed in the manufacture of insecticidal compounds, but the combination of zinc-arsenic is new and its toxicity is higher than either creosote or zinc chloride. The solution is made by dissolving the chemicals in water and when ready for use is clear and nearly colourless. It is used cold and penetrates the wood nearly twice as easily as creosote, while leaving the timber practically unchanged in appearance. As soon as the treated wood is exposed to the air, the evaporation of the solution brings about the necessary chemical changes and precipitates the solution within the wood, where it remains insoluble and permanent. It is immune to loss from all weathering influences, but is ready to put an end to any infection or fungus spores that may appear. One of the outstanding characteristics of this solution is that it is not corrosive to steel treating equipment; in fact, the solution seems to be a definite inhibitor of corrosion.

Compounds of copper with arsenic have also been used, but these copper solutions are corrosive to steel and leave the wood light green in colour. Another substance, which operates on a different principle than either the zinc arsenite or the copper arsenic compounds, is barium carbonate. Inasmuch as the fungi produce acidic substances they can exist only in acidic environment. Barium carbonate, being alkaline in nature, tends to neutralise any acids with which it comes in contact and if present in wood in sufficient concentration it will completely neutralise the acids produced by fungous organism and thus make it impossible for the fungus to live. The treating solution is a clear, colourless water solution of barium hydroxide which penetrates wood with great ease. On exposing the treated wood the carbonic acid of the air converts the soluble barium hydroxide to insoluble barium carbonate, precipitating the latter within the wood structure where it will remain indefinitely, non-volatile and insoluble in water.

Results of the tests are given in the article and also descriptions of the treatment methods and plant. It is claimed that the Zinc Arsenite treatment costs only one-fourth of the creosote treatment, and also reduces the weight and being clean simplifies handling. The poles so treated can be painted with ordinary paints and can thus be used in city streets without risk to passers-by. Wood so treated will not support combustion and does not increase in electric conductivity.

Owing to the limited accommodation at our disposal, the Board of Editors is compelled to announce that single copies of Journals up to Vol. XIX. cannot be supplied after December 31st, 1928. A number of copies will be retained to make up volumes for sale, but it is regretted that only a few complete sets of volumes will be available, as several issues have been entirely sold out.

HEADQUARTERS NOTES.

EXCHANGE DEVELOPMENTS.

The following works have been completed :—

Exchange.	Type.	No. of Lines.
Burslem	New Auto.	990
Chatham	,,	1330
Chesterton	,,	100
Edinboro' Central	,,	8720
Exeter	,,	1990
Hanley	,,	2335
Longton	,,	680
Newcastle-under-Lyne	,,	490
Rainham	,,	140
Snodland	,,	130
Stoke	,,	700
Southport	,,	3000
Southwick	,,	110
Strood	,,	320
Trentham	,,	200
Topsham	,,	90
Shrewsbury	Auto. Extn.	300
Leek	New Manual	580
Maryhill	,,	480
Toll London	,,	Positions.
Finchley	Manual Extn.	1740
Giffnock	,,	800
Sale	,,	420
Salisbury	,,	460
Waterloo (Lvpl.)	,,	960
African & Eastern	P.A.B.X.	60
Brintons	,,	40
Brysilka	,,	20
Dewhursts	,,	30
Electra House	,,	170
Electrical Federation	,,	80
Heinemans	,,	30
Jaeger Ltd.	,,	10
Nelson Corporation	,,	60
Philips, J. & A.	,,	30
Vickers & Sons	,,	30
West Bromwich Union	,,	60
Wood Green Council	,,	40
Wolverhampton Union	,,	30

Orders have been placed for the following new works :—

Exchange.	Type.	No. of Lines.
Ardwick	New Auto.	3045
Colchester	,,	1140
Collyhurst	,,	1913
Mitcham	,,	1480
National	,,	9400
Cheltenham	Auto. Extn.	535
Paisley	,,	860
Paignton	,,	290
Torquay	,,	570
Byfleet	New Manual	700
Camberley	,,	260
Canford Cliffs	,,	820
Hornchurch	,,	880
Valentine	,,	1500
Ealing	Manual Extn.	2050
Hatch End	,,	300
Margate	,,	820
New Cross	,,	900
Northwich	,,	180
Old Swan (Lvpl.)	,,	1050
Port Talbot	,,	300
Speedwell	,,	2480
Sydenham	,,	400
Tandem	,,	—
Wallasey	,,	3620
Willesden	,,	1700
Woolwich	,,	480
Worthing	,,	860
Armstrong Siddeley	P.A.B.X.	125
Dunlop Rubber	,,	20
Halifax Corporation	,,	50
Pearson Dorman & Long (B)	,,	Modfcns.
Pearson Dorman & Long (S)	,,	40
Southport Corporation	,,	100
St. Helen's Corporation	,,	80

A very successful gathering took place at the Manchester Hotel on Tuesday evening, 3rd January, in connection with the second annual dinner and dance of the Headquarters Equipment Section Swimming Club.

Altogether 96 members and friends assembled, being welcomed on arrival by the President, W. J. Bailey, Esq., and Miss Bailey.

At the conclusion of an appetising menu the toast of the King and Royal family was loyally responded to and was followed by toasts of The Club; The Visitors; The Committee; The Hon. Photographer; The Hon. Secretary, Mr. G. Brown; the Ladies and the Gentlemen.

Mrs. G. Brown graciously presented the prizes which had been won by the following members after a keen competition :—

44 Yds. Handicap.

1st, Mr. Hollinghurst, a cigarette case.
2nd, Mr. S. D. Hull, case of knives.
3rd, Mr. S. J. Husband, book on gardening.

Diving.

1st, Mr. J. Reading, pipe.
2nd, Mr. H. A. Ashdown, egg boiler.

3rd, Mr. M. C. Cooper, Eversharp pencil; and Mr. S. A. Waters, jam jar.

Novices' Race.
Mr. R. W. Sawyer, rose bowl.

Two violin solos were pleasingly rendered by Mr. L. V. Gorman, who also acted as M.C. for the dance which followed and lasted until midnight. The orchestra carried out its duties very ably and responded to repeated encores.

The Swimming Club, apart from its beneficial effects to the individual member and its encouragement of the acquirement of a most useful art, has developed the sporting spirit in its best sense and has been the means of facilitating social life and intercourse outside official hours of duty and during the summer organised a pleasurable healthgiving outing to the Surrey Hills.

Professor Jarvis has been appointed Instructor and swimming practice is held summer and winter on Wednesday evenings, at the Westminster Baths, Great Smith Street.

It is suggested that other Sections might well follow their lead.

ONE HUNDRED AUTOMATIC EXCHANGES.

With the opening of Armley Exchange in the Leeds Area on Saturday, 10th March, 1928, the number of public Automatic Exchanges brought into service in Great Britain reached a total of 100. A list of the exchanges in the order of opening is given below.

(In the case of Hereford, which appears twice in the table, the original Lorimer installation has been replaced by Messrs. Siemens No. 16 type equipment).

It will be seen that initial multiple capacity has been provided for 179,360 lines with an ultimate capacity of 257,915.

	Exchange.	*Contractor.*	*Date of opening.*	*Multiple Capacity.*	
				Initial.	*Ultimate.*
1	Epsom	A.T.M. Co.	18. 5.12	1100	1500
2	Hereford (see later entry 2a)	Lorimer	1. 8.14	—	—
3	Darlington	W.E. Co.	10.10.14	1200	2800
4	Accrington	A.T.M. Co.	13. 3.15	1200	1500
5	Chepstow	A.T.M. Co.	7. 7.15	200	200
6	Newport	A.T.M. Co.	14. 8.15	2600	3500
7	Portsmouth	A.T.M. Co.	29. 4.16	5200	7000
8	Paisley	A.T.M. Co.	15. 7.16	1700	2600
9	Dudley	W.E. Co.	9. 9.16	800	1600
10	Blackburn	A.T.M. Co.	14.10.16	3400	4400
11	Leeds	A.T.M. Co.	18. 5.18	9600	15000
12	Grimsby	Siemens	14. 9. 8.	3000	3300
13	Stockport	Siemens	23. 8.19	2400	2400
14	Ramsey	Siemens	24.10.21	80	80
15	Hurley	Siemens	20.12.21	80	80
16	Southampton	Relay	15. 7.22	480	920
17	Fleetwood	Siemens	30. 6.23.	3500	5600
18	Hadleigh	A.T.M. Co.	16. 2.24	125	125
19	Dundee	G.E. Co.	15. 3.24	4500	4500
20	Broughty Ferry	G.E. Co.	15. 3.24	600	1000
21	Marton	A.T.M. Co.	22. 3.24	300	500
22	Blockley	A.T.M. Co.	28. 3.24	25	50
23	Swansea	Siemens	9. 8.24	3500	5800
24	Sketty	Siemens	9. 8.24	470	500
25	York	A.T.M. Co.	15.11.24	1600	2000
26	Risca	A.T.M. Co.	16. 6.25	100	100
27	Cwmbran	A.T.M. Co.	16. 6.25	100	100
28	Kirkcaldy	Siemens	27. 6.25	700	1400
29	Torquay	A.T.M. Co.	31.10.25	2300	3000
30	Paignton	A.T.M. Co.	31.10.25	700	1400
31	Chapeltown	A.T.M. Co.	8.11.25	2100	2100
32	Roundhay	A.T.M. Co.	8.11.25	2100	2100
33	Headingley	A.T.M. Co.	8.11.25	2000	2400
34	Stanningley	A.T.M. Co.	8.11.25	1000	1600
35	Shrewsbury	A.T.M. Co.	9. 1.26	1300	1800
36	Hayling Island	A.T.M. Co.	13. 1.26	200	260
37	Gosport	A.T.M. Co.	13. 1.26	600	800
38	Ipswich	A.T.M. Co.	20. 3.26	2000	3300

	Exchange.	*Contractor.*	*Date of opening.*	*Multiple Capacity.*	
				Initial.	*Ultimate.*
39	Morriston	Siemens	19. 6.26	300	500
40	Cheltenham	A.T.M. Co.	28. 8.26	1700	2800
41	West Hartlepool	Siemens	25. 9.26	1200	1900
42	Hartlepool	Siemens	25. 9.26	200	300
43	Chesterfield	Siemens	25. 9.26	1000	1800
44	Staveley	Siemens	25. 9.26	100	200
45	Bedford	S.T. & C. Co.	2.10.26	1500	2800
46	Edinburgh	Siemens	2.10.26	9300	14600
47	Morningside	Siemens	2.10.26	2500	4400
48	Murrayfield	Siemens	2.10.26	1700	2900
49	Newington	Siemens	2.10.26	2100	3600
50	Coventry	G.E. Co.	20.11.26	3300	5400
51	Foleshill	G.E. Co.	20.11.26	700	1000
52	Cosham	A.T.M. Co.	8.12.26	200	200
53	Oxford	S.T. & C. Co.	11.12.26	2500	2500
54	Gloucester	A.T.M. Co.	12. 2.27	1500	3000
55	Harrogate	G.E. Co.	26. 2.27	2900	5500
56	Sheffield	Siemens	5. 3.27	6300	9000
57	Broomhill	Siemens	5. 3.27	2800	3500
58	Sharrow	Siemens	5. 3.27	1800	2600
59	Attercliffe	Siemens	5. 3.27	1000	1500
60	Beauchief	Siemens	5. 3.27	1200	1900
61	Owlerton	Siemens	5. 3.27	800	1200
62	Ecclesfield	Siemens	5. 3.27	300	300
63	Woodhouse	Siemens	5. 3.27	200	300
64	Oughtibridge	Siemens	5. 3.27	100	100
65	Halifax	S.T. & C. Co.	18. 6.27	3400	4000
66	Colwyn Bay	Siemens	9. 7.27	1400	1700
67	Llandudno	Siemens	9. 7.27	1200	2000
68	Burnley	G.E. Co.	20. 8.27	2300	3600
2a	Hereford	Siemens	10. 9.27	800	1100
69	Wakefield	Siemens	15.10.27	1000	1800
70	Sandal	Siemens	15.10.27	300	500
71	Fforestfach	Siemens	29.10.27	100	200
72	Brighton	Siemens	12.11.27	4700	6900
73	Hove	Siemens	12.11.27	4200	6200
74	Preston	Siemens	12.11.27	1000	1400
75	Portslade	Siemens	12.11.27	400	600
76	Rottingdean	Siemens	12.11.27	200	400
77	Holborn	A.T.M. Co.	12.11.27	9800	10000
78	Exeter	G.E. Co.	19.11.27	2100	3500
79	Topshâm	G.E. Co.	19.11.27	200	400
80	Hanley	G.E. Co.	26.11.27	1300	2000
81	Burslem	G.E. Co.	26.11.27	1100	2200
82	Longton	G.E. Co.	26.11.27	700	1100
83	Stoke-on-Trent	G.E. Co.	26.11.27	900	1500
84	Newcastle-u-Lyne	G.E. Co.	26.11.27	700	1000
85	Trentham	G.E. Co.	26.11.27	200	500
86	Chesterton	G.E. Co.	26.11.27	100	200
87	Southport	A.T.M. Co.	3.12.27	3700	5400
88	Birkdale	A.T.M. Co.	3.12.27	1600	2500
89	Churchtown	A.T.M. Co.	3.12.27	1000	2000
90	Southwick	Siemens	16.12.27	200	400
91	Nottingham	A.T.M. Co.	28. 1.28	7500	14000
92	Arkwright	A.T.M. Co.	28. 1.28	1000	1500
93	Basford	A.T.M. Co.	28. 1.28	1400	2200
94	Sherwood	A.T.M. Co.	28. 1.28	1200	3200
95	Leicester (Advance portion)	Siemens	18. 2.28	3400	—
96	Wigston	Siemens	18. 2.28	400	700
97	Western Park	Siemens	18. 2.28	300	400
98	Syston	Siemens	18. 2.28	300	500
99	Bishopsgate	A.T.M. Co.	3. 3.28	8500	10000
100	Armley	A.T.M. Co.	10. 3.27	700	1200

THE LATE MR. W. BROWN.

There are still many readers who remember Mr. William Brown, Head of the Telephone Section at Headquarters from 1901 to 1911, who was laid to rest in Highgate Cemetery on the 11th January last. Able references to Mr. Brown's work and responsibility in connection with the establishment of telephone service with Paris—opened in March, 1891; with the acquisition of the Trunk Lines by the Postmaster-General in 1896; with the introduction of Post Office Local Common Battery Exchanges; and finally in 1911 with the acquisition of the National Telephone Coy.'s plant—appeared in the Journal for January, 1912, on the occasion of his retirement. His service with the Post Office commenced at the transfer of the Telegraphs to the State in 1870 when he was appointed telegraphist at Newcastle-on-Tyne. In his junior position he soon began to show that close and continual application to work which distinguished him throughout his life. He was chosen as a member of what was then known as the Local Special Staff, a group of officers selected on account of proficiency to attend on occasions when large volumes of telegraph work had to be expeditiously disposed of—at Newcastle and elsewhere. He took keen interest at this early stage, in the electrical and mechanical principles and arrangement of apparatus with which he had to deal—at a time when information was not easy to obtain, and when few troubled about it. When in the course of a few years the telephone appeared he quickly became associated with the operation of the Post Office Exchange at Newcastle, which for a long period was a prominent feature of the system of the country. His marked ability in this duty at once won for him favourable notice and appreciation in the Engineer-in-Chief's Office at Headquarters, with the result that in the early " Eighties " he was called to London to join that Staff, and he remained upon it, latterly and for many years the head of that important branch of work, to the end of his official life. He threw himself with energy into taking his share in the administration, working, and development of the Telephone System: a duty which at times placed a very heavy load of responsibility upon him. He was aided by a remarkably good memory, which made a master of detail in complicated systems of telephone work and in their history. For extended periods he worked long hours daily. with little leisure even at week-ends—a devotion to duty which probably did harm to his health, and contributed to his extraordinary susceptibility to frequent attacks of epidemic influenza. In whatever work he engaged, he secured the full confidence of those under whom, or with whom he served—successive Engineers-in-Chief, colleagues of his own rank, and officers and men of all grades. He made friends all over the country. A trusted and genial friend himself, a real worker, thoroughly informed and helpful, he was widely esteemed: and those who were intimate with him and survive him will cherish the memory of his sterling qualities and remember him with affectionate regard to the end of their lives.

E.C.

We regret to announce the death, which occurred on Sunday, the 26th February last, of Mr. F. H. Bailey, who, for many years was Executive Engineer, in charge of the E.-in-C.'s General Testing Branch, Studd Street Depôt. Mr. Bailey, who retired at the age of 60 years in 1924, has suffered indifferent health for some considerable time, but the news of his dealh will be received with regret by his many friends and colleagues.

J. M. G. TREZISE.

After completing his engineering education at King's College and being associated with the late Sir William Preece in the pioneer days of electric lighting, Mr. Trezise entered the Post Office on the 15th December, 1890, and thus completed 37 years service on his retirement on the 31st December, 1927. As showing the great developments during this period, his first employment was in charge of a steam-driven electric light station capable of a maximum output of

MR. J. M. G. TREZISE.

120 K.W. at 110 volts Direct Current, while the Headquarters sub-station at the date of his retirement had a full load capacity alone of 3000 kilowatts, the input being at 11,000 volts three-phase 50 periods.

Mr. Trezise's ability was quickly recognised and in June, 1891, he was transferred from the charge of the small station at the G.P.O. to be n charge of the Electric Light and Power Staff at Mount Pleasant, from which date commenced his long and productive association with the late Mr. M. F. Roberts. Promotion to a second-class engineership came in November, 1897, after which he took rapid strides to first-class engineer n January, 1898, second-class technical officer in December, 1902, assistant-superintending-engineer in May, 1908, first-class staff engineer in October, 1909, and Superintending Engineer in charge of the Metropolitan Power District in December, 1910, which appointment he retained until the date of his retirement.

During his stay at Mount Pleasant he was responsible under Mr. Roberts for the design of Mount Pleasant and also the Savings Bank steam-generating stations, of which the former was at that date the largest in the Post Office, and as large as many in considerable-sized towns. Having seen these developments, as well as the electric lighting and power equipment of the associated buildings, brought to successful completion, he was transferred to the Engineer-in-Chief's Office in December, 1902, after which he was soon selected to accompany Mr. Roberts on a Continental tour of inspection of High-Tension Power Stations and Transmission Lines, which were in a more forward state of development than in Great Britain owing to cheap water power and the long distance to be covered. This tour was arranged to obtain information in connection with the projected Post Office Power Station on the river-side at Blackfriars. On his return in September, 1904, Mr. Roberts and himself received the thanks of the Postmaster-General for their report and recommendations, the soundness of which is shown by the fact that they were adopted and the Blackfriars Power Station was built and successfully operated for 15 years, when economic conditions and the development of large power stations necessitated closing it down.

During these busy years Mr. Trezise found time to pursue his favourite hobby of Photometry and as early as 1896 had already produced an illumination photometer which was in advance of the time, and would bear comparison with many in use at this date; by 1914 he had developed a photometer including a device which he patented for giving a clear and distinct screen which could be largely magnified without introducing errors. The intervention of the War prevented the exploitation of this photometer, but it has not been improved upon to this day.

During the post-war period Mr. Trezise has taken a large interest in the work of the British Engineering Standards Association and has acted as the Post Office representative on many Committees. As evidence of the value of this work the Association has invited him to continue as Chairman in his personal capacity of those Committees for which he formerly acted in his official capacity.

His authoritative knowledge of illumination was recognised by his selection by the Institution of Electrical Engineers to represent them on the National Illumination Commission of Great

Britain, a position he still holds and in which capacity he attended the International Commission on Illumination at Geneva in 1924.

Sufficient has perhaps now been said of Mr. Trezise's technical achievements; suffice it to say that as a man of a somewhat reserved and unassuming disposition he was yet the staunch friend of those fortunate enough to gain his confidence, though he could be a doughty opponent when the necessity arose.

Mr. Trezise is taking a well-earned rest in the South of France and Pyrenees for the benefit of his own and his daughter's health, and the best wishes of his friends for good health and happiness in his retirement will go with him.

E.H.W.

LONDON DISTRICT NOTES.

Telephones.—The changes in the number of exchange lines, extensions and stations during the quarter and the totals on 31st December, 1927, were as follows:—

	Increase	Total
Exchange Lines ...	7,858	326,932
Extensions ...	5,092	276,467
Stations	11,728	549,912

Exchange Works.—Bishopsgate automatic exchange—the second of the "Director" type—was opened on March 3rd, 1,325 subscribers and 1,846 junctions being transferred from the existing manual exchange. On March 10th, 3,300 subscribers were transferred from Avenue, Central, City, Clerkenwell, Clissold, East, London Wall and North exchanges. The equipment, for 8,000 subscribers immediately and 9,400 ultimately, was installed by the Automatic Telephone Manufacturing Company to a specification prepared by the Engineer-in-Chief, and is similar to that of the Holborn Exchange described on page 17.

At Hatch End a new exchange (C.B. No. 10) was opened on the 7th December last and at Merstham a new exchange of similar type was brought into use on the 21st December.

At Barnes a new C.B. exchange, known as Prospect, was opened on March 14th when 700 subscribers were transferred from Richmond Exchange, 300 of whom already had Prospect numbers.

At Edgware a new C.B. exchange, installed in the building which, later, will accommodate an automatic exchange, was opened on March 8th.

The temporary Terminus exchange situated in the old Holborn building was opened on March 7th and the temporary Ambassador exchange in the Paddington premises is nearing completion.

At Finchley an extension of 1,300 lines was completed during February. Other extensions are nearing completion at Chiswick, Riverside and Wanstead.

Pneumatic Tubes.—In Lloyd's imposing new building in Leadenhall Street, E.C., opened by His Majesty the King on March 26th, a pneumatic tube service has been installed between the telegraph room on the ground floor, adjoining the magnificent marble Market Hall and Threadneedle Street Branch Office. The tube passes through the floor to the night telegraph room in the basement, through a diverting switch and thence to the street and the instrument room at the Branch Office. Separate power plant has not been provided as power for the service in both directions is obtaind from the exhaust of the C.T.O. tubes at the Branch Office, being connected to the terminal *via* a system of valves. The night service is operated from the night telegraph room in the basement direct to the instrument room at the C.T.O. by means of the diverting switch referred to above and a similar switch in the day tube connecting the Branch Office to the C.T.O., power then being obtained from the mains at the C.T.O.

A diverting switch has been fitted on a C.T.O.—West Strand-War Office trunk tube, *i.e.,* an "up" tube to the War Office Centre. By turning this switch from its normal position, and applying vacuum at the War Office, "up" working can be maintained in the event of a failure of power at the C.T.O., thus rendering the War Office Centre independent of the C.T.O. power supply.

Two docket tubes, power driven, have been installed recently at Branch Offices; one at Harrow and the other at Dover Street. Both tubes are operated by " Fans, Centrifugal," and are controlled by switches at either end which enable the power to be cut off when the tube is not working, thereby effecting appreciable economy. At Dover Street the tube replaced a Gipe Carrier, the last of this type in service in London.

External Plant.—The changes in mileage during the three months ended 31st December, 1927, and the totals on that date were as follows :—

Line Mileage.

	Increase Miles.	Total Miles.
Pole Line	45	5,824
Pipe Line	187	9,437

Single Wire Mileage.

	Overhead Miles.	Underground Miles.	Total Miles.
Telegraphs ...	—	194	24,983
Telephones (Ex.) ...	314	71,883	2,194,015
,, (Trunk).	84	2,574	69,675
Spare*	—	—	104,246

London readers will be sorry to hear of the death of Mr. J. L. Brown, formerly Executive Engineer in the London District, who retired on pension some two years ago. Mr. Brown died at his home in Alexandra Road, St. John's Wood, on the 20th February, and was buried in Hampstead Cemetery on the 24th. " Jock," as he was known to his colleagues, came over with the Company in 1912 and was greatly esteemed for his personal qualities, not only by his old colleagues but by the many friends he made in the P.O. service.

* *i.e., excluding small gauge local conductors.*

LOCAL CENTRE NOTES.

LONDON CENTRE.

The Session was opened on the 11th October by Mr. F. I. Ray, B.Sc., F.H.D., A.M.I.E.E., who read a paper on " Satellite working in Automatic Areas." The paper dealt with the development of Satellite working and was illustrated by slides and demonstration apparatus. There was a large attendance and a good discussion.

On the 8th November Messrs. T. Fewster and F. Johnston, A.C.I.S., of the Northern Centre, gave a paper on " Accounting as a Function of Management." Various phases of Accounting were considered and particular reference was made to the Department's costing systems. A good discussion followed and the many points raised were suitably replied to by Mr. Fewster.

On the 13th December Messrs. A. H. Jacquest, A.M.I.E.E., and L. H. Harris, M.Sc. (Lond.), A.C.G.I., gave a paper entitled " Sparking and Arcing at Relay Contacts and the use of Spark Quench Circuits." The paper was illustrated by slides and there was a good discussion, many visitors making valuable contributions based upon the experience of manufacturers.

The meeting of 10th January was unique. Mr. F. A. B. Lord, of Messrs. Dennis & Co., exhibiting films showing " Cable Manufacture and the Laying of the Anglo-Dutch Cable " by Messrs. Felton & Guilleaume. There was a record attendance and the interested audience showed its appreciation.

On 7th February Messrs. C. W. Brown, A.M.I.E.E., and R. J. Hines, B.Sc., gave a paper entitled " The Problem of the P.B.X. connected to a Public Automatic Exchange." The paper was illustrated and a good discussion ensued. Mr. Brown replied with his accustomed facility.

INFORMAL MEETINGS.

The Informal Meetings have so far been very successful. They deal with the more humanistic features of the Profession and the interest aroused by these subjects and the freedom of discussion has been evidenced by the increased attendances.

The first of these meetings was held on the 25th October and was opened by Capt. J. G. Hines, M.I.E.E., the subject being " The Telephone Engineer and his job." The discussion was of sustained interest throughout and only the strict enforcement of a time limit enabled the meeting to close at the usual time.

On 22nd November Major Brown, O.B.E., opened a discussion with the intriguing title "Some things we all think we know."

Fresh from his visit to Sweden, Major Brown dealt with the different methods of carrying out Construction work and the consequent saving in time as compared with this country. The subject was dealt with fearlessly and yet moderately. The subsequent discussion was very keen and the opinions expressed very varied.

On 24th January Mr. G. T. Evans opened a discussion on "Some small Current Rectifiers and their Characteristics." The talk dealt with valve rectification and the application of rectifiers for the elimination of batteries in connection with Wireless Receivers. The consequent discussion centred on the latter aspect of the subject, many speakers being desirous of obtaining information about inexpensive methods of obtaining suitable current from either D.C. or A.C. Mains.

VISITS.

Successful visits have been made to

H.M.T.S. "Monarch."

W. T. Henley's Telegraph Co.'s Works, Gravesend.

The Mullard Radio Valve Co., Ltd.

For the success of these visits the Committee desires to place on record its appreciation of the courtesy of those who made the visits so instructive and enjoyable. T.H.

SOUTH EASTERN CENTRE.

Mr. C. T. Crisp, Executive Engineer, Brighton North Section, South Eastern District, retired on the 23rd February, 1928, having completed 43 years' Established Service. Prior to his appointment as Sectional Engineer in charge of the Old Brighton Section he passed through the following grades :—

(1) Sorting Clerk and Telegraphist, Ipswich.
(2) Relay Clerk, Eastdean and North Walsham.
(3) Engineer, Second Class, Metropolitan North District.

Mr. Crisp is a man of fine and strong character, with a high sense of duty, and knows what he thinks and acts on it. He exerted a great and good influence on all members of his staff, who regarded him with high esteem and much affection. In times of emergency his quiet and unruffled manner dispelled feelings of funk, calmed the "windy" and inspired confidence which enabled serious difficulties to be overcome without fuss or friction.

Mr. Crisp has left behind him at Brighton a record of work performed which will be a lasting memorial to his whole-hearted devotion to duty and an example to the younger generation of engineering officers to emulate.

He always took a very keen interest in the affairs of the Institution of Post Office Electrical Engineers, and contributed several articles to the Journal. As a result of his personal efforts a record sale of the Journal was reached in the Brighton Section.

Mr. Crisp was presented by Mr. F. Tandy, Superintending Engineer, with a fine gramophone and library of records on behalf of the staff at a gathering on the 23rd February. Mr. W. McCormack, Executive Engineer, Brighton South, and Mr. E. Armstrong, Assistant Engineer, spoke of Mr. Crisp's good qualities of heart and mind. Mr. Crisp replied in a characteristic manner.

SOUTH WESTERN CENTRE.

RETIREMENT OF MR. A. E. CHAPMAN, M.I.E.E., BRISTOL.

On February 29th, 1928, Mr. A. E. Chapman, the senior Assistant Superintending Engineer of the South Western District, retired from the Service on attaining the age limit.

Mr. Chapman entered the service as a Telegraphist in the Central Telegraph Office, London, on the 25th March, 1882, where he remained until 1891, when he was promoted to North Walsham, the first Post Office Hughes Repeater Station in this country. In December, 1895, Mr. Chapman took up the position of 2nd Class Engineer at Holloway Factory, where he was engaged in testing the first Trunk Switch Sections. In September, 1896, he was transferred to Leicester. Here the substitution of Quad G.P. cables by paper core cables was successfully effected.

Promoted to 1st Class Engineer in July, 1903, he remained at Leicester until 1905, when he was transferred to Nottingham, on the amalgamation of the Nottingham and Grantham Sections. In May, 1909, as a result of a severe illness, aggravated by exposure to severe climatic conditions, during an extensive breakdown of the Department's plant, he was transferred to the newly-formed South Western District, with headquarters at Yeovil, where he remained until the acquisition of the National Telephone Co. System in 1912, when the Headquarters of the Section was transferred to Bournemouth.

In November, 1913, Mr. Chapman was appointed Assistant Superintending Engineer at Bristol, where he remained until the date of his retirement. During the War, Mr. Chapman spent the period June, 1916—June, 1918, at Reading, where he was closely associated with the Superintending Engineer of the South Midland District in the provision of Military, Naval and Air Force Systems of communications.

With the retirement of Mr. Chapman, the Department loses a valuable officer and the South Western District a good friend. His genial and generous nature appealed to all grades of the staff. Endowed with all the instincts of a true gentleman, no one has ever had to cultivate a "thick-hide," as a shield against his control. His uniformly courteous and genial disposition and his readiness with which he afforded his colleagues and others the benefit of his wide and varied experience, secured for him a large measure of esteem. In short, he was a gentleman first and an official afterwards, and in his retirement we sincerely trust that he and Mrs. Chapman will have many years of well-earned leisure and happiness in their new home at Bournemouth, whither he has already removed.

Prior to his retirement from the Service Mr. Chapman was entertained by his colleagues and friends at a Smoking Concert held at the Rotary Club, Bristol.

Mr. A. Gray, Assistant Superintending Engineer, presided over a very large company and among those present were Mr. E. J. Eldridge—as alert and young looking as ever—and other friends of the various Departments of the Post Office.

The Chairman, after extending a hearty welcome to the visitors, especially the ladies, read letters of apology for absence and expressions of good wishes from Messrs. Pugh (Postmaster-Surveyor), Millar (District Manager), Fish (District Survyor, Office of Works)) Pink (Sectional Engineer, Bristol), Wise (Sectional Engineer, Exeter), Rattue (Sectional Engineer, Canterbury), Major Cottle (Assistant Engineer, Plymouth) and others. During the evening a large and varied programme of music—vocal and instrumental—arrangd by Messrs. H. H. Brown and Emlyn Jones, Senr., was carried through, the gentlemen taking part being Messrs. Emlyn Jones, Ellis, Hodge, Chivers, Sleigh, Baker, Drew, Hall, Alexander, Hargreaves, Turner, Ross, Saunders, Aickin, Grant and the Chertsey Glee Singers, with Messrs. Emlyn Jones, Jnr., and Sutton as accompanists.

In an interval in the programme, the Superintending Engineer, Major Batchelor, D.S.O., M.C., in a very humourous and appropriate speech made the presentation, which comprised a Columbia Cabinet gramophone, suitably inscribed, and Amplion Cone Loud Speaker and a case of bowls.

Mr. Chapman, who was obviously affected by the warmth of his reception, in thanking the staff on behalf of himself and his wife, said he had a difficulty in expressing in adequate words the many kindnesses that had been shown him by the presentation or such handsome and useful mementoes. He had, he said, been in the service of the Department for upwards of 46 years and in that time had seen many changes. In again thanking the staff, he expressed the hope that the future might hold much prosperity for them all.

The concert was undoubtedly one of the most successful in the annals of the South Western District and the Committee of Management (Messrs. Weir, H. H. Brown, Cockshott and Alexander) is to be congratulated on the admirable success attending its arrangements.

The catering arrangements in the hands of Messrs. Bennett, Buckley and Bell were also of a high order. A.G.

SOUTH MIDLAND CENTRE.

At the opening meeting of the 1927-28 Session a lecture, "Satellite working in Automatic Areas," was delivered by Mr. F. I. Ray. The lecturer did not read from his typed notes, copies of which had been circulated. At the outset he defined a "Satellite Exchange," explained the application of that definition and stated that at the end of 1927 the satellite exchanges should number 63 with a total capacity of about 100,000 lines.

The arrangements at Newport, Mon., with its two satellites at Risca and Cwmbran were explained. In this area all calls from Risca and Cwmbran, including those from one subscriber at Risca or Cwmbran to another connected with the same exchange were completed by means of the junctions to and from Newport.

From the comparatively simple conditions in the Newport area the lecturer passed on to the more complex systems where it was possible to discriminate in the selection of junctions for (*a*) multi-exchange and (*b*) trunk calls. It was shown that extreme care was necessary before a numbering scheme for a particular area was adopted.

Seven distinct schemes of working, each of which had been designed for a different requirement, were described and details of the methods in use at Leeds and Hanley were outlined.

The limitations of the Brighton Multi-office Exchange area, which consisted of two main and four satellite exchanges where the names of the six exchanges in the area are printed on the dial, were explained.

The scheme designed by the Post Office staff, known as the "Post Office Discriminating Selector Repeater" system, was described and its working shown by means of a demonstration set. The lecture was illustrated by 21 lantern slides.

Mr. McMullen, of Southampton, who was unable to be present, sent a written list of questions relating to the Portsmouth area, and Messrs. Wakefield, Halton, Lewis, Atkins, Capt. Linsell and Mr. Bolton contributed to the discussion.

After the points raised by Mr. McMullen and the verbal enquiries had been answered, the Chairman passed on to Mr. Ray the hearty thanks of the audience.

The November meeting was devoted to a paper by Mr. J. Innes entitled "Edinburgh Auto. Multi-office Transfer." This helpful paper was full of pracical methods of overcoming difficulties of the change of sysem, but as it is to be printed there is no need to make a detailed record here. The slides were much appreciated.

The time left for discussion was too short to enable all members who were interested to take part, but the Lecturer briefly replied to the points raised by Major Harris, Messrs. Atkins, Halton, Nichols, and T. Martin.

There was enthusiastic applause at the end of the lecture and the Chairman thanked Mr. Innes on behalf of the members present.

The comparatively small attendance at the meeting held on the 21st December was probably due to the proximity of the Christmas holidays. Mr. V. Smith read a paper on "Electrolytic Action." It was stated in the introduction that 130 cases of cable damage by corrosion had occurred in the South Midland District during the past twelve months.

Part I. of the paper dealt with damage by chemical action. The four chief causes of damage due to soil constituents were outlined, and it was maintained that the main safeguards against the trouble are dry conduits, the liberal application of petroleum jelly and the use of specially protected cables. Hints on the selection and packing of samples for analysis were given, and this section of the paper concluded with a description of unusual and interesting cases.

In part II. the general use of Tester No. 36 for measuring the strength of a current in a cable sheath was described. The methods and difficulties experienced in detecting leakages from tramway systems were explained and then the procedure when electric lighting mains were suspected was set out. Leakages from the Department's own plant were next to receive attention. They were mainly due, it was shown, to the earth plates at Exchanges being of comparatively high resistance.

The lecture was well illustrated by a number of diagrams.

Twelve members, Messrs. Traviss, Godfrey, Reeves, Bolton, Roach, Dwyer, Halton, Major Harris, Messrs. Wakefield, H. W. Peck, Mullens and the Chairman took part in the discussion during which several points of difficulty appeared to be elucidated.

The Chairman, describing the paper as a good and practical one, thanked Mr. Smith for his work.

On January 25th, the subject taken by Mr. W. H. Arnold was "Thrust Borers and Thrust Boring." The Acting Chairman in introducing the lecturer thanked Mr. Arnold for his zeal in undertaking at short notice to read his paper two months earlier than the date arranged for it in the programme.

It was contended that the use of thrust borers in suitable situations will frequently save expenditure. The advantages of the borer were greatest when conduits had to be laid under railway level crossings or in congested thoroughfares. The best results are obtained when a man with practical experience of the machine travels with it and supervises its use. It was foreshadowed that boring would be resorted to in future even under inexpensive surfaces in rural areas.

Conclusions drawn from experience were given about the types of soil encountered and the method of overcoming obstructions.

A description of the machine known as the Mangnall Irving type G.1 was given. The successive operations were explained in connection with excavating for the pits, inspecting the machine before use, lowering into pit, fixing the pilot bar, the rough and afterwards the fine setting of the machine, launching the pilot, boring the hole and drawing in the pipes.

The paper was illustrated by twelve slides.

In the discussion Messrs. Gilpin, Lewis, V. Smith, Logan, Halton, Summers, Major Harris, Messrs. S. E. Naylor, Wakfield, Roach and Capt. Linsell took part.

The proceedings ended with hearty applause for Mr. Arnold. A.W.L.

SCOTLAND WEST CENTRE.

The fourth meeting of the current session was held in the Royal Technical College, Glasgow, on the 22nd February, the lecturer for the day being Mr. F. I. Ray, B.Sc., D.F.H., A.M.I.E.E., who took for his subject "Satellite Working in Automatic Areas."

The lecture proved to be one of the most interesting and instructive fixtures held locally for some time. The subject was illustrated by means of lantern slides, and demonstrations were given on the working apparatus which had been set up. On conclusion of the lecture several questions were put which were productive of further information, and an opportunity was given for examination of the apparatus.

H. C. MacC.

NORTH WALES CENTRE.

The following is the Committee for the 1927-28 Session :—

Chairman—Mr. R. A. Weaver, M.I.E.E.
Vice-Chairman — Mr. C. A. Jackson, A.M.I.E.E.
Executive Engineers—Mr. G. Richardson, A.M.I.E.E.
Assistant Engineers—Mr. H. P. Lloyd.
Chief Inspectors—Mr. J. Frost.
Clerical Staff—Mr. G. H. Carrier.
Inspectors—Mr. J. C. Spiers.
Draughtsmen—Mr. A. W. Allport.
Local Secretary and Librarian—Mr. J. G. K. Donaldson.

The session was opened on the 12th October, 1927, when Mr. R. T. Robinson, A.M.I.E.E., of the Engineer-in-Chief's Office, read a paper on "Motor Transport in the Engineering Department." The lecturer, after an historical survey of the early experiments in motor transport, enlarged on the post-war expansion of this particular activity and on the various types of vehicle which have been developed in later years to meet the peculiar requirements of the Engineering Department.

The second meeting was held on the 9th November, when Mr. J. Ree, of the Mullard Wireless Service Co., Ltd., read a paper entitled "Thermionic Valves and Distortionless Amplification." The lecture, which was illustrated by a series of slides, dealt largely with the requirements in valves and couplings for good reception and particularly with respect to the comparative impedances of valves and transformers.

The third meeting was held on the 8th December at Birmingham, and was preceded by a visit of inspection to the Midland Exchange. On this occasion Captain J. Coxon, A.M.I.E.E., was the lecturer and the subject of the paper was "Exchange Power Plant." The field covered was a very extensive one and despite a prompt start it was found necessary to curtail the lecture somewhat, in order that some time might be left for the ensuing discussion.

On the 11th January, 1928, Mr. C. G. A. McDonald read a paper entitled " The running of a large Wireless Station," opening with a description of the plant at Leafield and of the difficulties which have been experienced in operating the arc transmitter. Subsequently he described the short wave transmitters at Leafield and also certain experiments which have been made in screening and focussing the transmissions so as to obtain beam effects.

The fifth meeting was held on 1st February, 1928, the subject of the paper being " Satellite Working in Automatic Areas," by Mr. F. I. Ray, B.Sc., D.F.H., A.M.I.E.E., of the Engineer-in-Chief's Office. The lecture was illustrated by an unit demonstration set showing all the operations between a parent and two satellite exchanges, and with the aid of this and numerous slides Mr. Ray provided a very clear exposition of the discriminating schemes in Director and Non-Director areas.

The sixth meeting was held on 22nd February, 1928, when Mr. R. Sheppard read a paper entitled " Exchange Construction." In this paper a survey of the field of the Department's Staffs was made with a collection of notes on the layout and planning of small exchanges, transfer arrangements, construction details, contract works and contractors organisations.

The keen interest taken in the meetings has been marked by the discussions, which have been well maintained on each occasion.

The attendances have been from 80 to 100.

SOUTH LANCASHIRE CENTRE.

An account of the opening meeting of the Session appeared in the January issue of the Journal. Four other well-attended meetings have since been held and the interest in the proceedings has been fully maintained.

On November 14th, 1927, Mr. C. W. Brown, A.M.I.E.E., of the Engineer-in-Chief's Automatic Training School, read a paper on " The Director—Its applications and the functions performed." A particularly clear outline of the working of the Director equipment was given and the reasons were stated for its adoption in the densely telephoned area of Manchester. Keen interest was displayed by the larger number of members and visitors present, and, in the discussion which followed, many points were cleared up by the lecturer.

On December 12th, 1927, a paper was read by Mr. T. Cornfoot, M.I.E.E., entitled " The Administration of an Engineer's Section." This gave an interesting account of the various duties of administration and the difficulties attendant upon the organisation of staff, control of expenditure, etc. Several lantern slides were shown dealing more particularly with the procedure adopted in the Liverpool External Section, and the general information given in the paper was greatly appreciated by the members present.

At a meeting held on January 24th, 1928, members of the North Western Centre of the Institution of Electrical Engineers were present by invitation, together with several members of the Postmaster's staff. A joint meeting of the local Centres of the two Insitutions has now become an annual feature and has done much to strengthen the cordial relations between the memberships of the respective Institutions in the locality. On this occasion a paper entitled " Recent Developments in Power Engineering in His Majesty's Post Office " was read by Mr. H. C. Gunton, M.B.E., M.I.E.E., Chief Power Engineer of the Post Office. The paper proved to be exceedingly interesting, and a good discussion followed. An expression of thanks was moved, on behalf of the visitors, by Mr. A. B. Mallinson, M.I.E.E., Chairman of the N.W. centre of the Institution of Elecrical Engineers.

On February 6th, 1928, the fifth meeting of the session, a paper entitled " Accounting as a Function of Management," was presented by its joint authors, Messrs. T. Fewster and F. Johnston, A.C.I.S., of the Northern Centre of the Institution. The paper was read by Mr. Johnston, who dealt very fully with the subject, and certain modifications of present practice, suggested in the paper, provoked a spirited discussion. Subsequently Mr. Fewster very ably replied to the points raised by the various speakers.

NORTH WESTERN CENTRE.

The third meeting of the 1927-28 Session was held at Preston on the 16th January, 1928, when a paper entitled " Traffic Arrangements as they apply to Automatic Exchange Transfers " was read by Mr. A. L. Barclay (Telephone Traffic Superintendent).

Mr. Shackleton presided over a good attendance which included the District Manager (Mr. S. O. Allen) and a number of his staff.

Mr. Barclay took as an example the actual arrangements made in connection with the recent Southport Automatic Exchange Transfer and covered the following items: — Preliminary Traffic Data, Staffing, Control Sheets, Distribution Lists, Switchboard Lay-out, Co-operation with the Engineering Department, Visiting Subscribers' Premises, Demonstration Set, Advance Transfer, Call Offices, Main Transfer, Post Transfer, Service Inspections, etc. The lecture was illustrated by specially prepared diagrams.

On the 13th February, 1928, a paper entitled " Rebalancing a Cable " was read by Mr. T. Woodhouse, A.M.I.E.E.

Mr. Woodhouse opened his lecture with a review of the sources from which interference can be traced and indicated means of eliminating the trouble. The question of the necessity for rebalancing a cable was fully dealt with and the various tests described at length. The paper was illustrated by diagrams and schedules and was followed by a useful discussion.

D. Barratt.

Death of Mr. R. A. Jones.

It is with deep regret we record the death of Mr. Robert Alexander Jones, Executive Officer Higher Grade (Staff Officer), of the Superintending Engineer's Office, North Western District, which occurred in a Nursing Home on the 13th February, after an urgent operation. Mr. Jones was taking a few days Annual Leave at his home in Southport when his sudden illness occurred, and the news of this followed quickly by the announcement of his death came as a great shock to his colleagues and friends in the North Western District.

Born on the 17th April, 1869, and appointed Sorting Clerk and Telegraphist at Liverpool in June, 1885, he had completed nearly 43 years' service, and his death adds yet another to the sad list of zealous members of the staff who have fallen out of the ranks within hailing distance of retirement.

He was promoted to the position of Junior Clerk in the Engineering Department in July, 1891, and commenced his engineering career in Manchester, the headquarters of the old North Western District. Passing uninterruptedly through the various clerical grades, and serving in many Districts (North Eastern, North Wales, North Midland), he was back again in the North Western District, at Manchester, as Chief Clerk in the beginning of 1904. In November, 1911, he moved to Preston, the Headquarters of the new North Western District, where he found full scope for his outstanding organising and administrative abilities, and where he served the Department for the past 16 years.

In his official life, R.A.J., as one of his many friends in a letter of condolence remarks, stood for a great tradition; he was first and foremost a Department's man, but in his dealings with his staff his high sense of justice was tempered by strong human sympathy, which had its foundations in his deep religious convictions.

He served on the Local Committee of the I.P.O.E.E., and from time to time contributed interesting and useful papers, notably his recent paper entitled " Accidents on Duty " and his last paper read during the last session, " Some Curiosities of Official Literature."

In his unofficial life he found time for many public activities. He was a Warden and Councillor of St. Luke's Church, Southport, and past-Chairman of the Southport Branch of the English Church Union. He also took an active interest in the Boy Scout movement. A master of pure English and possessing a keen sense of humour he was a pleasant conversationalist.

The funeral took place on February 16th. The service was held at St. Luke's Church, Southport, and the burial was at Wallasey. In addition to the Superintending Engineer and Assistant Superintending Engineer and representatives of the Surveyor's Department and all ranks of the Engineering Staff, the funeral was attended by many representative public men, including the Mayor of Southport.

He leaves a widow and son and daughter and the heartfelt sympathy of his many colleagues and friends throughout the Service will be added to that which goes out to them from within the District in their sad bereavement.

May he rest in peace.

S.U.

EASTERN CENTRE.

Mr. J. E. A. Sorrell.

Mr. J. E. A. Sorrell.

By the retirement of Mr. J. E. A. Sorrell, another well known and popular officer is lost to the Telegraph side of the Engineering Department. Entering the Post Office service as Telegraphist at the C.T.O. in January, 1884, he proceeded to qualify himself for technical duties and was a pupil of Sir William Slingo.

After considerable experience on telegraph repeater work in the C.T.O. he was transferred to the Engineering Department as a Relay Clerk (Lower Section) in 1894, serving for a short time at East Dean, after which he was stationed at Llanfair P.G. (Anglesey).

In March, 1900, he was appointed to the Engineer-in-Chief's Office as 2nd Class Engineer. After only a year's service in this capacity he returned to the repeater service for private reasons and was stationed at North Walsham. May, 1905, saw him promoted to Relay Clerk (Upper Section) and placed in charge at North Walsham. Here many strenuous years were spent in telegraph experiments between England and Germany that resulted in replacing Hughes by duplex Baudot working. In 1910 he was appointed a member of the Anglo-German Commission, a position for which, by virtue of his extensive experience, he was especially suitable.

The cessation of Anglo-German communication at the outbreak of War in 1914 resulted in the closing down of North Walsham Repeater Station, and Mr. Sorrell was sent to take charge at Warrington, where a telegraph Repeater Station had been established. November 1st, 1915, saw him back again on the East coast as officer-in-charge of the Lowestoft Repeater Station, where he remained until his retirement on the 18th October, 1927.

During the last two years of his service the Repeater Station was removed to a new building, and he had the privilege of being in charge of the most up-to-date station in the country.

Mr. Sorrell's activities in his leisure hours were numerous and he will not find the years of his retirement hang heavy.

His many colleagues past and present wish him health and happiness in his retirement. He will always be remembered as a keen servant of the Department yet at the same time a considerate and kindly chief.

J.A.S.M.

BOOK REVIEWS.

" Wireless Direction Finding and Directional Reception." By R. Keen, B.Eng. (Hons.), Sheffield, A.M.I.E.E. The Wireless World, Iliffe & Sons, Ltd. 490 p.p. 21/-.

This book is a second edition of a book first published in 1922 under the title of " Direction and Position Finding by Wireless." The present edition is expanded to form a comprehensive treatise on all systems of directional reception. The Wireless Direction Finder has furnished the seaman with a valuable auxiliary to the appliances on which he relies to navigate his ship. With the increasing use of radio as a means of telegraphic communication, the properties of directional reception have become of great importance to the Radio Engineer.

The author's treatment of the theoretical side of the subject is ample for the purposes of the book; a comprehensive Bibliography, to which appropriate references by numbers are made in the text, appears at the end of the book, and furnishes a useful guide to those who wish to make a more intensive study of the subject, The author deals with the practical side of the subject in the fullest and clearest manner. The book is singularly free from error, which gives evidence of careful preparation and proof reading, and can be confidently recommended to all those interested in the subject dealt with.

Chapters devoted to " maps " and " Notes on Field and Nautical Astronomy " will be found of especial use to those responsible for installing direction finding installations, and a chapter on " Fault clearing and Maintenance " should prove useful to those responsible for the maintenance of the plant, although this last chapter is particularly applicable to the Bellini Tosi system as developed by the Marconi Co.

F.W.D.

" History of Radio Telegraphy and Telephony." By G. G. Blake, M.I.E.E., F.Inst.P. Publishers: Messrs. Chapman & Hall, Ltd. 25/- nett.

The compass of this book includes both a brief historical review of the history of wireless and a compendium of inventions, schemes and proposals which have been concerned in the development of radio telegraphy and telephony.

Both sections of the work are valuable by the extensive references given to the published articles, proceedings of various societies and patent specifications which deal with the subject matter outlined by the author.

The references, which total 1,125, are conveniently tabulated in one list, and there is a good index.

Some instances may be noticed where the original article describing an improvement or invention might advantageously have been quoted instead of or in addition to later publications on the subject. In this connection original papers in the American Institution of Electrical Engineers on " Wired Wireless " and " Beverage Antennæs " has not been referred to, but later articles on the same subject are noted. The most prominent patents in modern wireless and the earlier invention and " disclosures " which are of great interest and importance to the designer and user are included in the review. One notable omission is that of Lee and Hogan's adaptation of the Fessenden Heterodyne Receiver which is not mentioned.

The method of cross-reference is generally clear, but a few obscurities or errors occur. In describing the Bellini and Tosi Direction Finding Method it is stated that an account of their work appeared in 1907, but the references given are to publications in 1919 and 1920 and an original article by Bellini published in the *Electrician* in 1914 is overlooked.

The book can be recommended to the student of wireless history, as well as to those interested in the application of patents which have now lapsed or are still in force.

A.S.A.

" Practical Radio Telegraphy." By Nilson and Hornung. McGraw Hill Publishing Coy., Ltd. Price 15/-.

This work which is of American origin is intended to serve as a text book for students who wish to pass the examination for a Radio Operator's License in the U.S.A.

The earlier part of the book deals briefly with the elementary principles of the subject, and the later chapters are confined to descriptions of ships' wireless equipments peculiar to modern American practice.

The authors state in their preface that the trend in the design of modern radio equipment is from the spark to the valve type; one could have wished therefore that a good deal of the considerable space devoted to spark might have been cut down to make room for some extension of the chapters on valve transmitters. The chapter on Direction Finding Equipment might also have been usefully extended to include further technical details of the receivers: no diagrams of either of the types described were given.

The book is profusely illustrated and for those who are interested in ships' wireless equipment can be recommended as giving a comprehensive survey of American maritime wireless practice.

H.B.T.

" The Call Indicator System of Automatic Telephony." (A. G. Freestone). Sir Isaac Pitman & Sons, Ltd. 6/-.

This book embodies concise and clear expositions of the circuit arrangements employed in this secondary, but very important, part of the scheme for the conversion of a metropolitan area to automatic working.

The descriptions are not over-burdened with detail and the uniformity of method adopted in presenting the various facilities and circuit functions is very helpful to a proper appreciation of the sequence of operations.

It is unfortunate, however, that the inset diagrams have been placed without sufficient regard to the need for continuous reference between them and the letter press, and before settling down to a study of the book readers would be well advised to remove the diagrams to the end of the respective circuit descriptions.

There are no material errors to record, and, apart from the reference to the intermittent click facility (p. 57), which has not been provided, the subject matter is thoroughly up to date.

With the exception, perhaps, of a few minor modifications either already adopted or in contemplation, the utility of the book is not likely to decrease with the lapse of time and its acquisition can be recommended both to students who desire to improve their acquaintance with the application of machine switching principles to modern circuit problems and also to those others, whose interest is of a more practical nature.

J.R.

" Wireless Principles and Practice." By L. S. Palmer, M.Sc., Ph.D. London: Longmans Green & Co. 504 pp. 18/-.

The volume under consideration is stated to be specially intended for the student and for the Electrical Engineer who wishes to become conversant with wireless.

The work is divided into twelve chapters, the first five being concerned with the principles of Radio, while the remaining seven deal with practical applications.

The first and second chapters on Wave Motion and Wireless and on High Frequency Alternative Currents and Oscillatory circuits respectively give concise but adequate treatment of the subject.

Chapter three is devoted to Wireless Circuits and Aerials for Transmission and reception. It deals with circuit components, wavemeters, decrement and selectivity and aerials and radiating systems, including a few words on the measurements of aerial constants. We should expect to find some reference to wave antennæ beyond a solitary reference in the Bibliography.

The following chapter is on the subject of Special Circuits, which are dealt with under three headings, viz.: Rejector and Acceptor Circuits, Coupled Circuits, and circuits for Duplex and Dual operation. The first and third are dealt with fairly briefly, the second very thoroughly. It is perhaps a matter of regret that the subject of filters does not receive more adequate treatment in view of the importance of such circuits in modern practice. Reference to the most informative source of information on filters, viz., The Bell Technical Journal, is also omitted from the Bibliography.

Chapter five is devoted to the theory of the wireless valve and contains sections on conduction through gases, electron emission from hot bodies, the two electrode valve characteristics, valve design and manufacture and finally four electrode valve characteristics.

Chapter six deals with spark arc and alternator methods for the generation of high frequency currents. It is noticed that the author falls into the popular error that the use of a spacing wave tends to interfere unnecessarily with other stations, whereas actual practice tends to indicate the reverse, owing to the absence of key clicks.

In the section on alternators it is surprising to find no reference to the Bethenod-Latour alternator used so widely in France at St. Assize, Lyons and Bordeaux.

The following chapter is devoted to the subject of the three electrode valve oscillator, while chapters 9 and 10 deal respectively with the detection and amplification of oscillatory currents. A description is given of a two wire telephone repeater; the author's figures for the normal spacing of repeaters are far too high.

Wireless Telephony is next dealt with, while a final chapter on Directional Wireless completes the work. In describing the single sideband suppressed carrier system of telephony the reader is rather led to infer that the main object of this system is to reduce distortion whereas the primary consideration is of course the reduction of the frequency band utilised.

The book gives a well-balanced and comprehensive survey of the whole field of radio communication, unnecessary elementary sections on electricity and magnetism, which so frequently form a goodly proportion of the contents of books on Radio communication, are absent, and the writer does not hesitate to use mathematics where the subjects call for it.

One of the most valuable features is the inclusion of a Bibliography at the end of every chapter divided into sections corresponding to the sections of the chapter. The Bibliography gives references only to articles in periodicals or proceedings of scientific societies, but does not give references to published books. In many cases references to such works would be useful to readers.

The book is undoubtedly the most up-to-date on the subject and it will have a wide sphere of usefulness as a work of reference for engineers and as a text book for students.

A.J.G.

"The Principles of Electric Power Transmission by Alternating Currents." By H. Waddicot, B.Sc., A.M.I.E.E., A.A.I.E.E. Published by Messrs. Chapman & Hall, Ltd. 21/- net.

This book, which is published at a very opportune time in view of the many power distribution schemes now proposed or being put in hand, deals with the electrical problems that occur in designing alternating current transmission lines. It is primarily intended to be a suitable text book for students pursuing this subject, but at the same time the problems have been treated practically and it will also be found useful to designers and engineers in charge of power transmission systems. Throughout the book the reader will find a large number of practical examples worked out in detail, both mathematical and graphical methods being used where possible.

After considering elementary principles the author deals with the electrical problems involved in short and long transmission lines. As the book is written to deal with the electrical problems of transmission the mechanical construction of the line is only slightly dealt with, but it is thought that the value of the book for general use would be improved if the chapter on overhead construction were amplified in future editions from this point of view.

Following the consideration of insulation of the line the method of maintaining constant the terminal voltage of the line with varying loads by installing idle running synchronous motors and modifying the power factor by varying the excitation is dealt with fully. This chapter is followed by the consideration of underground mains and an exposition of the economic principles of design, the final chapters dealing with problems caused in operation by normal and abnormal conditions, surges, lightning, etc., and the various protective devices necessitated and employed.

The book is well illustrated and useful references are given at the end of each chapter, to a larger number of technical papers dealing with aspects of the subject.

J.McG.

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

PROMOTIONS.

Name.	Grade.	Promoted to.	Date.
Arundel, D. S.	Assistant Engineer, N. Mid. District.	Executive Engineer, N. Mid. Dist.	1-2-28
Collis, S. A.	Inspector, Testing Branch.	Chief Inspector, E.-in-C.O.	1-10-27
Smith, B. J.	Inspector, S. Western District.	Chief Inspctor, S. Western District.	To be fixed later.
Cresswell, W. H.	Inspector, London District.	Chief Inspector, E.-in-C.O.	To be fixed later.
Meldrum, F. A.	Inspector, S. Lancs. District.	Chief Inspector, E.-in-C.O.	To be fixed later.
Josephs, H. J.	Draughtsman, Class II., Ldn. Dist.	Chief Inspector, E.-in-C.O.	22-12-27
Bull, S. W.	S.W.I., S. Western District.	Inspector, S. Western District.	28-1-28
Ryan, J. F.	S.W.I., S. Western District.	Inspector, S. Western District.	29-1-28
Sansom, W. S.	S.W.I., S. Western District.	Inspector, S. Western District.	21-1-28
Wilkinson, E.	Wayleave Officer, N.E. District.	Inspector, N. Eastern District.	1-2-28
Hay, H. E.	S.W.I., N. Eastern District.	Inspector, N. Eastern District.	To be fixed later.
Robinson, R.	S.W.I., Northern District.	Inspector, Northern District.	7-10-27
Scrafton, C. D.	S.W.I., Northern District.	Inspector, Northern District.	7-10-27
Madgwick, J. M.	S.W.I., Northern District.	Inspector, Northern District.	7-10-27
Pitloh, T. P.	S.W.I., Northern District.	Inspector, Northern District.	10-6-27
Hemming, M. H.	S.W.I., N. Wales District.	Inspector, N. Wales District.	20-11-27
Mason, H.	S.W.I., N. Wales District.	Inspector, N. Wales District.	24-10-27
Hargrave, A.	S.W.I., N. Wales District.	Inspector, N. Wales District.	1-1-28
Wilson, W. C.	S.W.I., N. Wales District.	Inspector, N. Wales District.	25-2-28
Rogers, A. H.	S.W.I., N. Wales District.	Inspector, N. Wales District.	24-10-27
Prichard, E. J.	S.W.I., N. Wales District.	Inspector, N. Wales District.	3-1-28
Corner, W. H.	S.W.I., N. Eastern District.	Inspector, N. Eastern District.	3-2-28
Lawrence, C. R.	S.W.I., N. Eastern District.	Inspector, N. Eastern District.	12-10-27
Porter, E. R. C.	S.W.I., Eastern District.	Inspector, Eastern District.	28-8-27
Harrison, H. W.	Tel. C.T.O.	Repeater Officer, Class II., North Walsham.	12-12-27
Hartnell, E. W. J.	S.C. & T., Bristol.	Repeater Officer, Class II., Lowestoft.	To be fixed later.
Flowers, T. H.	Probationary Inspector, E.-in-C.O.	Inspector, E.-in-C.O.	15-1-28
Brock, P. R. W.	Probationary Inspector, London Dist.	Inspector, London District.	
Boocock, R. O.	Probationary Inspector, N. Mid. Dist.	Inspector, N. Midland District.	
Bell, C.	Probationary Inspector, London Dist.	Inspector, London District.	
Lewis, N. W. J.	Probationary Inspector, London Dist.	Inspector, London District.	
Leckenby, A. J.	Probationary Inspector, London Dist.	Inspector, London District.	
Pitcairn, A. C.	Probationary Inspector, London Dist.	Inspector, London District.	
Groves, K. G. R.	Probationary Inspector, London Dist.	Inspector, London District.	
Collman, E. L.	Probationary Inspector, N. Dist.	Inspector, Northern District.	
Cawsey, A. J.	Probationary Inspector, S. Mid. Dist.	Inspector, S. Midland District.	
Ellis, H. O.	Probationary Inspector, S.W. Dist.	Inspector, S. Western District.	
Morgan, C. A.	Probationary Inspector, London Dist.	Inspector, London District.	
Ingram, C. P.	Probationary Inspector, N. Dist.	Inspector, Northern District.	
Penney, A. E.	Probationary Inspector, London Dist.	Inspector, London District.	
Porter, J. E.	Probationary Inspector, London Dist.	Inspector, London District.	
Bucknall, F. R. B.	Probationary Inspector, N. Dist.	Inspector, Northern District.	
Hobbs, H.	Probationary Inspector, S.W. Dist.	Inspector, S. Western District.	
Cherry, D. W.	Probationary Inspector, London Dist.	Inspector, London District.	
Francis, H. E.	Probationary Inspector, N.E. Dist.	Inspector, N. Eastern District.	
Knapman, D. E.	Probationary Inspctor, S. Mid. Dist.	Inspector, S. Midland District.	
Greening, F. C. G.	Probationary Inspector, London Dist.	Inspector, London District.	
Wilcockson, H. E.	Probationary Inspector, E.-in-C.O.	Inspector, E.-in-C.O.	
Coates, A. G.	Probationary Inspector, S. Mid. Dist.	Inspector, S. Midland District.	

TRANSFER.

Name.	From.	To.	
Pattison, B. C.	Inspector, Eastern District.	Inspector, N. Wales District.	1-3-28

RETIREMENTS.

Name.	District.	Grade.	Date.
Chapman, A. E.	S. Western.	Assistant Superintending Engineer.	29-2-28
Crisp, C. T.	S. Eastern.	Executive Engineer.	23-2-28
I'Anson, R.	N. Midland.	Executive Engineer.	31-1-28
Devonshire, T. E.	S. Midland.	Assistant Engineer.	31-12-27
Homfray, F. W.	S. Midland.	Chief Inspctor.	18-2-28
Crampton, G. H.	S. Midland.	Inspector.	31-12-27
Manion, J.	N. Eastern.	Inspector.	31-12-27
Chapman, O. E.	Eastern.	Inspector.	3-1-28
Davidson, G.	N. Eastern.	Inspector.	5-10-27

DEATHS.

Name.	District.	Grade.	Date.
Ashbee, A. W.	S. Western.	Chief Inspector.	24-11-27
Childs, P. J.	London.	Assistant Engineer.	8-2-28
Evans, J. W.	London.	Inspector.	11-1-28
Pagan, D.	Scotland East.	Inspector.	8-1-28

APPOINTMENTS.

Name.	Appointed to :—		
Jackman, A. J.	Probationary Assistant Engineer.		Open Competition.
MacWhirter, R.	,, ,, ,,		
Barron, D. A.	,, ,, ,,		
Holmes, M. G.	,, ,, ,,		
Dallow, J. E.	Probationary Inspector,	London Dist.	Limited Competition.
Birch, S.	,, ,,	London Dist.	
Joyce, R. M.	,, ,,	London Dist.	
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Other Changes.

Name.	Rank.	District.	Cause.	
Jones, R. A.	Staff Officer	N. Western	Death	13-2-28
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THE
Post Office Electrical Engineers' Journal

START-STOP PRINTING TELEGRAPH SYSTEMS.

(*Continued.*)

A. E. STONE, A.R.C.Sc.

(ii.) THE MORKRUM TELETYPE NO. 2A.

THIS is an improved form of the Morkrum Teletype, using the same 5 unit telegraph code but with type bars instead of a typewheel. The working speed is 60 words a minute, and the required character is printed on a paper tape by causing the corresponding typebar to strike sharply an inked ribbon as in an ordinary typewriter.

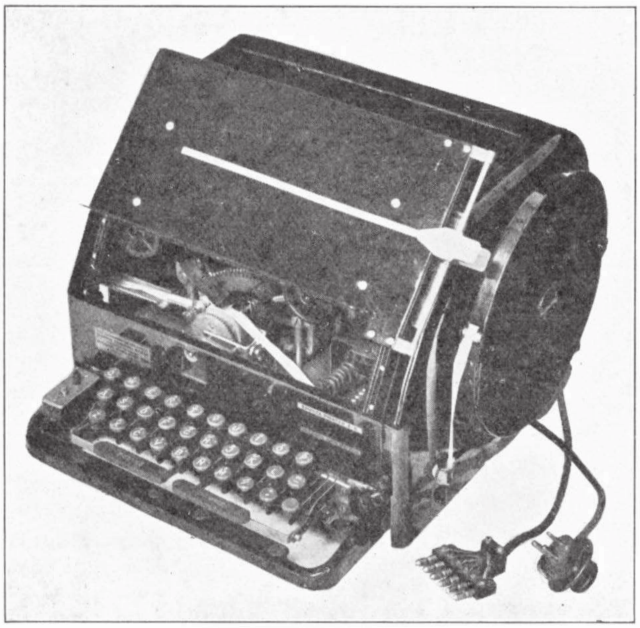


FIG. 1.—MORKRUM TELETYPE NO. 2A.

A general view of the instrument is shown in Fig. **1**, while the interior arrangements are shown in Fig. **2**. It has a single shunt wound motor of 1/20th H.P. for driving both the Receiving and the Transmitting portions of the instrument.

Transmitter Clutch Mechanism.—The actual transmitting mechanism is the same as that of the No. 1A machine, but the clutch mechanism for driving the Transmitter Cam Spindle is entirely different. In the Teletype No. 1A, when a key is held down, the cam spindle rotates continuously and the relative character is repeated so

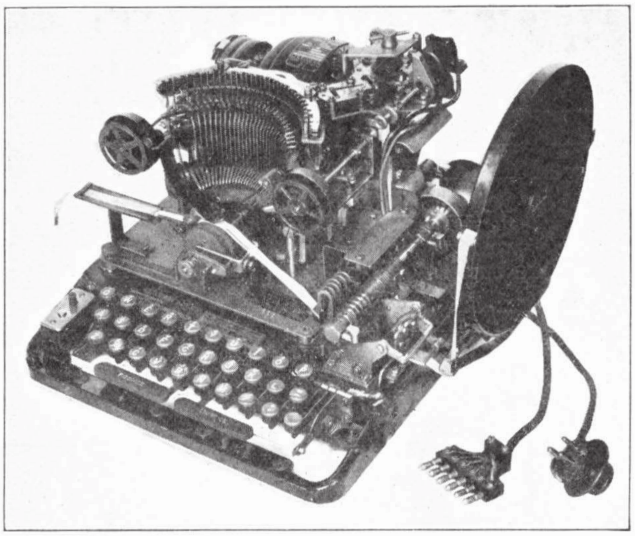


FIG. 2.—TELETYPE NO. 2A. COVER REMOVED.

long as the key is kept depressed. In the No. 2A machine, however, the character is transmitted once only, no matter how long the corresponding key is held down. The Clutch mechanism to effect this is shown in Fig. **3**. The Driving Ratchet is fixed to a shaft which is driven continuously by the motor. The Driven Ratchet engages with the spindle carrying the transmitting contact cams. The Clutch Spring tends to urge the Driven Ratchet into engagement with the Driving Ratchet, but normally is prevented from so doing by the Clutch Lever CL, the upper end of which, under the action of spring S2, bears against the Throw Out Cam forming part of the Driven Ratchet. Each Key Lever, in addition to moving the Selector Bars as explained in the case of the 1A Teletype, depresses a Universal Bar UB, which causes the Trip Off Pawl, TOP, to move forward and engage with the Clutch Lever Pawl, CLP. The latter is therefore turned slightly on its axis, causing the upper end of CL to move away from the Throw Out Cam, thereby allowing the Clutch Spring to move the Driven Ratchet into engagement with the Driving Ratchet and the Cam Spindle to be rotated. As TOP moves forward in the direction of the arrow X, it bears against the screw E2 which forces it down, thus disengaging it from CLP, at about the same instant that the Cam Spindle is set in motion. This allows both CLP and CL to return to their normal unoperated positions under the action of spring S2 quite independently of the time that the key is held down. Consequently the upper end of CL in bearing against the Throw Out Cam just before the Driven Ratchet completes one revolution, forces the latter from the Driving Ratchet and brings the Cam Spindle to rest at the end of the revolution.

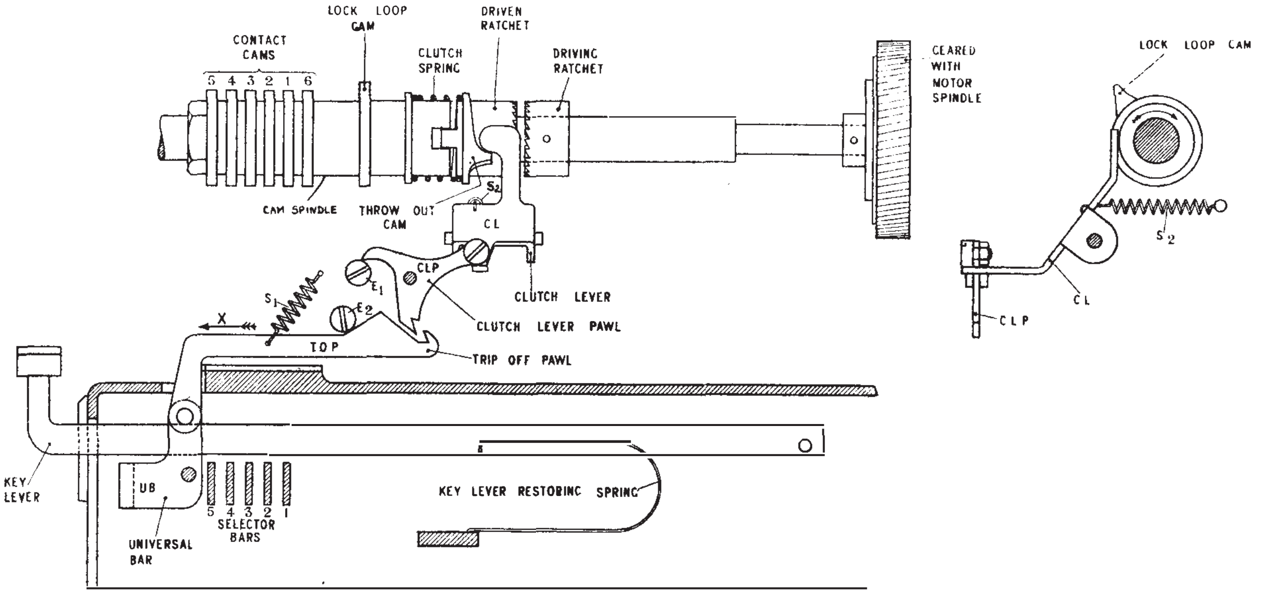


Fig. **3**.—Key Lever, Selectors and Clutch.

Printer Selecting Mechanism.—The Main Shaft, Figs. **4** and **5**, rotates continuously and carries on its upper end a Cam Sleeve which it drives by means of a friction Clutch. This consists of two felt washers FW, the upper one of which is held between a Retaining Disc RD, fixed to the main shaft, and the Cam Sleeve Disc CSD. The lower felt washer is held between another Cam Sleeve Disc CSD and the Driving Disc DD, which is keyed to the main shaft but is capable of sliding along it. The Clutch Spring S provides the necessary pressure between the components of the Clutch.

There is a single receiving electromagnet, as in the Teletype No. 1A, having its armature normally attracted when signalling is not taking place. In these circumstances the Cam Sleeve, see Fig. **4**, is held stationary because the Stop Arm SA fixed to it, buts against the Stop Pawl SP which is locked in position by the Stop Pawl Latch SPL. When the "Start" impulse de-energises the electromagnet, the armature is pulled away from the cores, and the plunger P, acting on the lever BCL, trips the Stop Pawl Latch SPL. This releases the Stop Pawl and allows the Cam Sleeve to be driven by the Main shaft. When the "Stop" signal re-energises the electromagnet, the armature is attracted and spring SPLS restores SPL, BCL and P. Spring SPS pulls SP back to its normal position where its projection Y is held by SPL. The Cam Sleeve is therefore stopped at the end of each revolution by SA coming against SP.

The armature of the electromagnet, Figs. **4** and **5**, has an extension AE which carries projections A and B. Mounted on the Cam Sleeve are seven cams, of which five, SC, are for setting

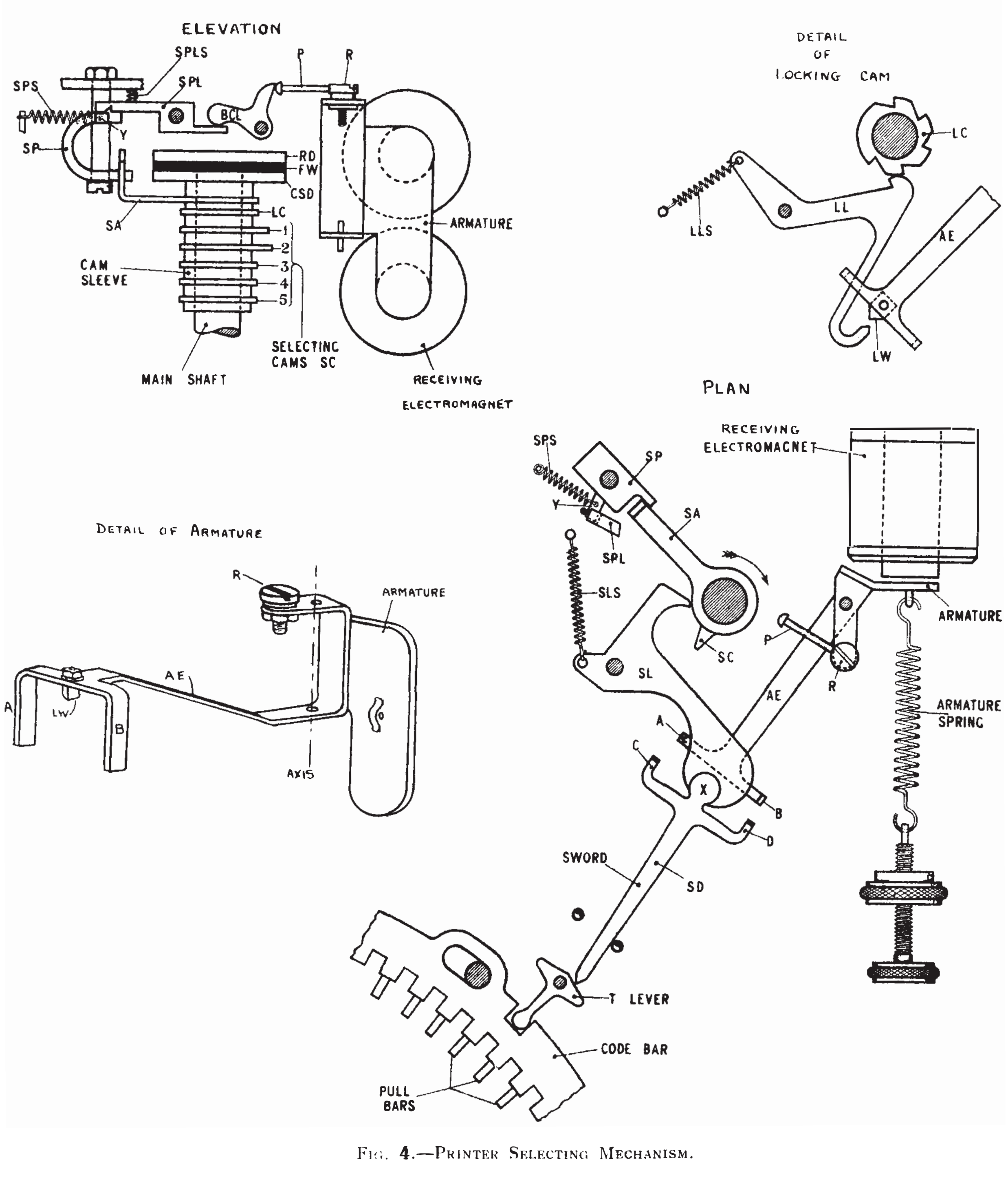


FIG. **4**.—PRINTER SELECTING MECHANISM.

five Code Bars; one, LC, is a locking cam, and the other, No. 6, in Fig. **5**, is for tripping a clutch to set the printing mechanism in motion. Associated with each Selector Cam SC is a Selector Lever SL, a Sword SD and a T Lever, by means of which the corresponding Code Bar is set.

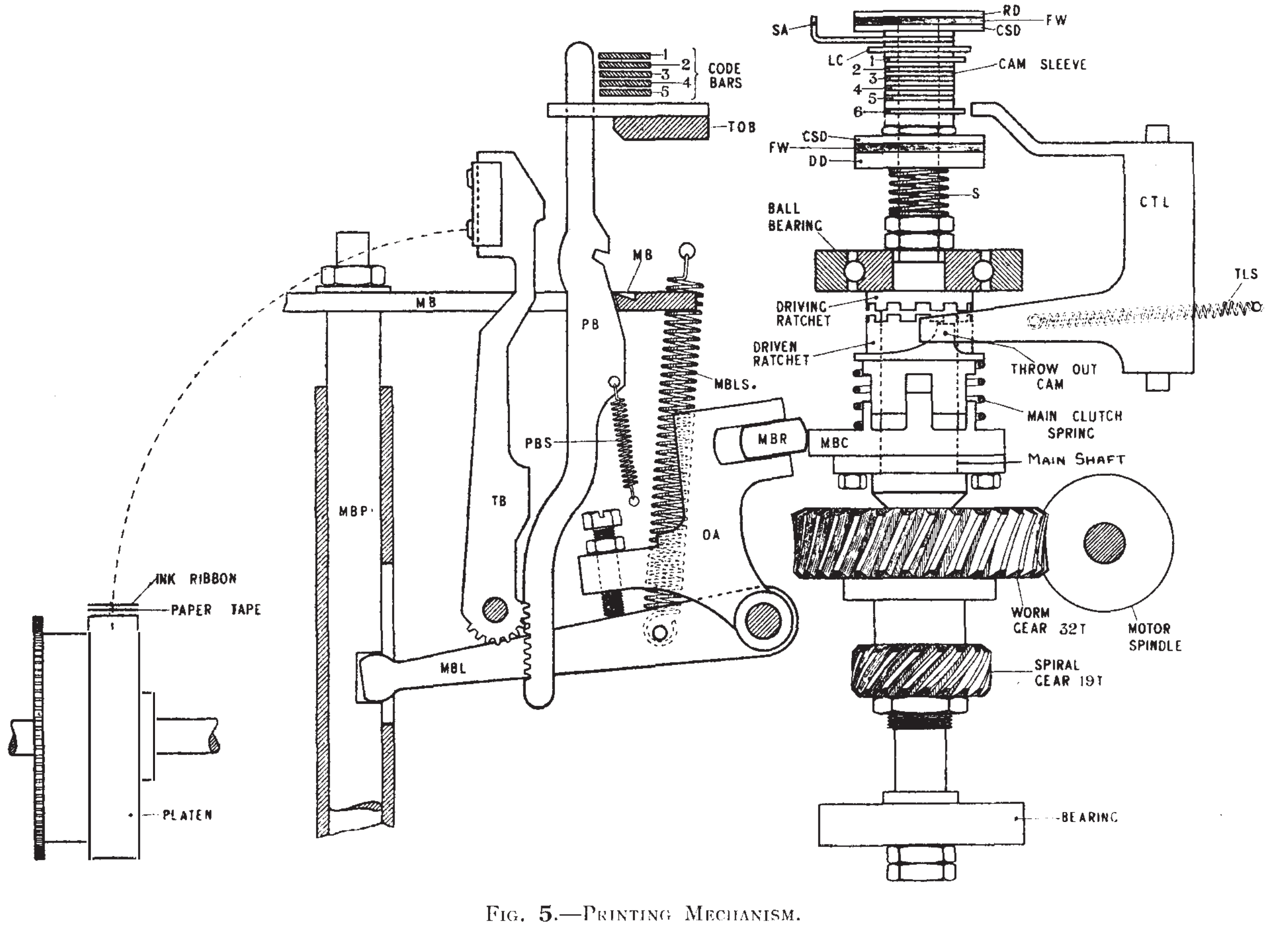


FIG. **5**.—PRINTING MECHANISM.

The Cam Sleeve starts to rotate immediately the " Start " impulse arrives; then after a short interval of time the first Selecting Cam SC1 acts on its Selector Lever SL causing it to move in an anticlockwise direction, carrying with it, its associated Sword SD. If the impulse following the Start signal is a marking unit, the armature of the electromagnet will be attracted and projection B of its extension AE will be moved into the path of the lug D of SD. Accordingly, as SD is carried forward by SL, D will come against B and SD will turn about X as a pivot in a clockwise direction, so that its lower end will move to the left hand side of its T-lever. As soon as SC1 clears the end of its SL, spring SLS causes SL to return to its normal position, communicating a downward thrust to SD which turns the T lever and moves Code Bar 1 to the right. If the next impulse is a spacing unit, the armature will be pulled away from the cores of the electromagnet by its spring and the resulting displacement of AE will position projection A in the path of lug C of SD. Cam SC2 now acts on its Selector Lever SL and this, in moving the associated Sword forward, causes its lower end to move to the right hand side of the corresponding T-lever. The subsequent restoration of SL causes Code Bar 2 to move to the left, or, if it is already to the left, will allow it to remain there. The other three code bars are positioned similarly, each being controlled by its own sword and levers. It should be noted that the five selector cams are staggered and act on their selector levers in succession.

The Locking Cam LC, Fig. **4**, is provided to hold the armature extension rigid during the period when a sword is striking one of its projections. LC has five notches, the relative positions of which correspond to the highest parts of the five selector cams. The toothed projection of the lever LL presses on the rim of LC and enters the notches consecutively as the cam rotates. At these times the pointed end engages with a Locking Wedge LW fixed to AE, holding AE rigidly either to the right or to the left when a sword is about to strike it.

Printing Mechanism. — Each code bar is notched along its front edge in a definite manner, arranged differently from the others. When the bars are in their normal spacing positions to the left, there is no set of notches in the five bars that is in alignment. This is shown in Fig. **6**, in which it will be seen that for the transverse position indicated by the line U, there are notches only in bars 4 and 5. If, however, bars 1, 2 and 3 are moved slightly to the right (marking position), then a set of notches will be in alignment at this position. Similarly for position H, bars 3 and 5 will have to be moved to the right to produce a set of aligned notches. The code for the letter U is 1, 2, 3 marking units, and 4, 5, spacing units; for the letter H it it 3, 5, marking units, and 1, 2, 4, spacing units.

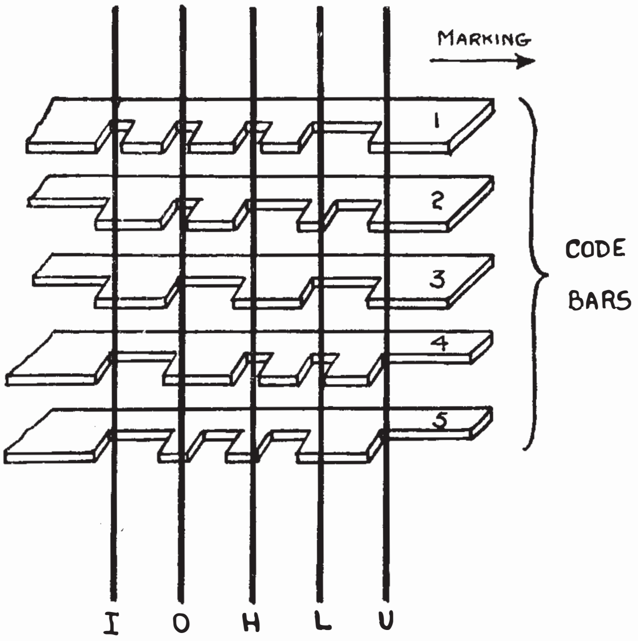


Fig. **6**.—Code Bars.

The lines U, L, H, O, I, etc., actually represent levers which can fall forward into the notches when they are aligned and the arrangement constitutes a device for selecting any particular lever according to the incoming code combination.

The printing mechanism is shown in Fig. **5**. The Main Bail Cam MBC and the Driven Ratchet are mounted on a sleeve through which the continuously rotating main shaft passes freely. The Main Clutch Spring tends to move the Driven Ratchet into engagement with the Driving Ratchet fixed to the Main Shaft, but is prevented normally from doing this by the end of the Clutch Throw-out Lever, CTL, which bears against the Throw-out Cam.

Immediately the code bars have been set and just before the Cam Sleeve comes to rest, cam 6 trips CTL allowing the two Ratchet Wheels to engage and to rotate the cam MBC. The shape of this cam allows spring MBLS to act on the lever MBL, tending to raise it and keeping it in contact with MBC, through the Operating Arm OA and the roller MBR. Thus MBL moves according to the contour of the cam MBC. The free end of MBL engages with the Main Bail Plunger MBP which is fixed to the Main Bail MB. In front of the code bars are a number of Pull Bars PB each of which is connected to a particular Typebar TB. MB normally holds these pull bars away from the edges of the code bars. The initial upward motion of MB allows the pull bars which is connected to the typebar of the selected character to be pulled into the aligned notches in the Code Bars by the spring PBS. As MB continues its upward movement it engages with a projection on PB and thus carries it upwards also. Consequently the rack on the lower end of PB causes the typebar to turn about its pivot and its free end carrying the type to move smartly downwards, striking the ink ribbon and printing the desired character on the paper tape. Near the end of its upward stroke PB meets the Trip Off Bail TOB, which throws it out of engagement with MB, allowing it to be returned to its normal position by the spring PBS. MB on returning to its normal position holds the pull bars away from the code bars, which may then be moved for the next selection.

Actual printing occurs after the selection for the next character has been stored up on the swords when the printer is working at its maximum speed. The selection is transferred to the code bars after the previously selected pull bar has been moved out of the notches.

Tape Feed Mechanism. — The paper tape passes from a roll mounted on the side of the instrument and through a Tape Guide TG, Fig. **8**, over a rubber platen. The latter is rotated by the platen shaft which carries a toothed wheel W3 gearing with a pinion on the Tape Feed Roller TFR.

The feed mechanism is shown in Fig. **7**. The Main Bail Plunger MBP in its upward movement acts on the roller attached to lever SOL, thus moving the Feed Pawl SFP downwards. On the return of MBP the spring S, which controls SOL, causes SFP to move upwards and to turn the Ratchet Wheed SRW one tooth in a clockwise direction. SRW is fixed on the spacer shaft which gears with the platen shaft as shown. Accordingly the platen is rotated, and as W3 gears with the Feed Roll the tape is fed forward one space immediately after printing has been effected.

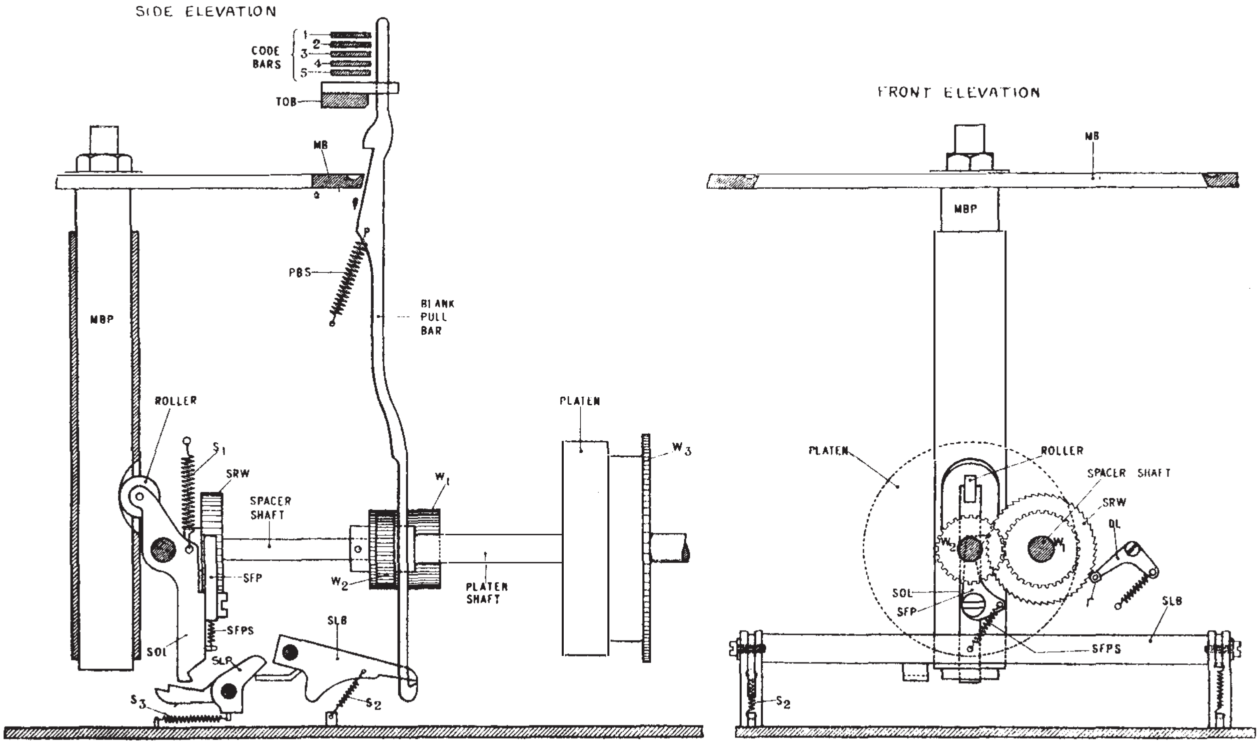


FIG. **7**.—TAPE FEED MECHANISM.

For speed checking purposes, the distant operator depresses a key which sends five spacing impulses and it is not necessary that the tape should be fed forward in these circumstances. It is therefore arranged that the corresponding pull bar in its upward travel shall engage with the Spacer Locking Bail SLB and pull it upwards. This allows spring S3 to move the Locking Pawl SLP into the path of the toe of SOL during the downward travel of MBP, thus preventing SOL from moving and feeding forward SRW and the platen. During the next cycle of operations, if another character is being received, SOL is moved far enough away from SLP to disengage from it as MBP moves upwards. Spring S2 then restores SLB and SLP to normal, and spacing is accomplished in the usual way when MBP descends.

Shift Mechanism (see Fig. **8**).—Each typebar carries two characters, the lower being the Primary, for letters, and the upper the Secondary, for figures, etc. The platen is held in the position shown, for printing letters, by the Carriage Locking Pawl, CLP, which engages

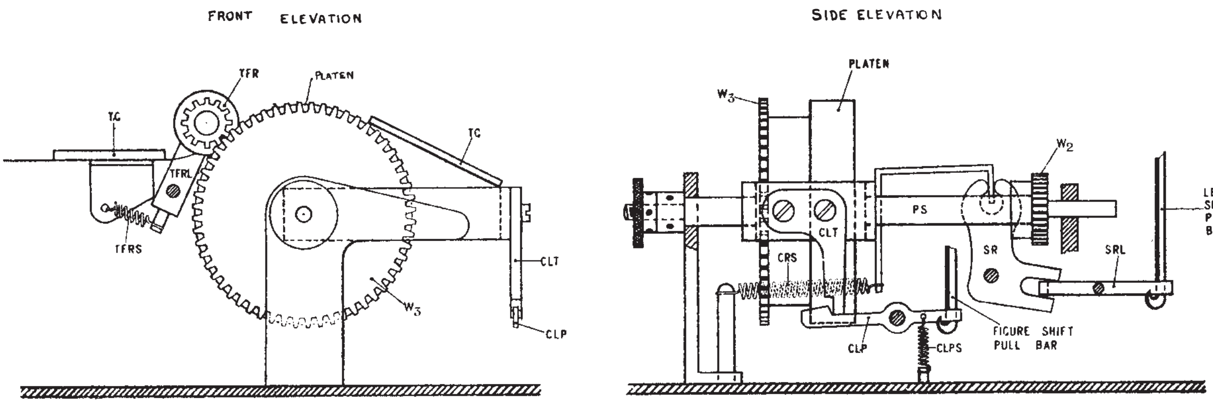


Fig. 8.—Shift Mechanism.

with the Carriage Locking Toe, CLT, fixed to the platen carriage. If it is desired to print Secondary characters, the distant operator sends the " Figure Shift " signal, which selects the Figure Shift pull bar of the Printer. When this pull bar moves upwards it lifts CLP and allows spring CRS to pull the platen to the left in the figure, which is towards the front of the machine. All printing following this operation will be of Secondary characters until the distant operator sends the " Letter Shift " signal. This selects the Letter Shift pull bar which, when it is pulled upwards, turns the Shift Rocker SR, thus moving the Platen to the right, in which position it is locked by CLP engaging with CLT.

Ink Ribbon Feed.—As in the case of a typewriter the ink ribbon is fed from one spool to another as the machine operates.

The Ribbon Feed Shaft, RFS, Figs. **9** and **10**, can be rotated and also be moved endwise to occupy one or other of two positions. It carries the Ratchet Wheel RFR, and in one position gears with the left hand Ribbon Spool Shaft, whilst in the other it gears with the right hand Ribbon Spool Shaft. The lever RFL, Fig. **9**, moves the pawl RFP forward each time the Main Bail Plunger MBP ascends. Spring S, attached to RFL, causes RFP to move backwards and engage with the teeth of RFR as MBP descends, thus turning the Spool Shaft RSS by means of the bevel gearing.

RFS is shown, in Fig. **10**, in gear with the right hand Ribbon Spool Shaft, feeding the ribbon from the left hand spool to the right. When the left hand spool becomes nearly exhausted, a rivet fixed to the ribbon moves lever A downwards, thus causing the lower end of the pawl P1 to be moved to the right into the path of the bail RRB. When MBP moves downwards, RRB engages with P1 and the motion

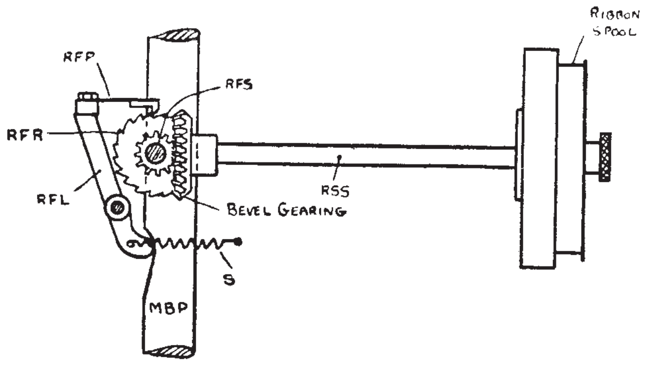


Fig. **9**.

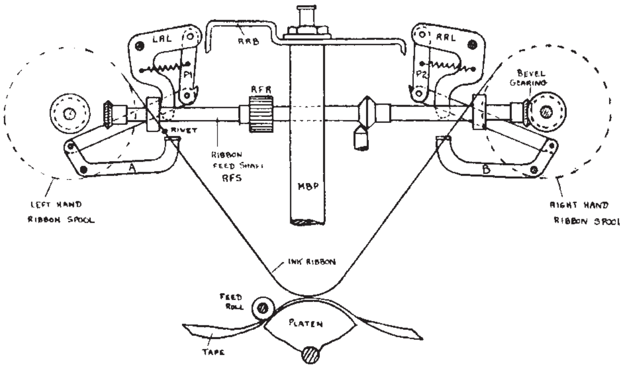


Fig. **10**.

Ink Ribbon Feed.

imparted to the pivoted lever LRL thrusts RFS to the left. This movement disengages the bevel wheels on the right and engages those on the left of RFS, thus driving the left hand Spool Shaft instead of the right hand Spool Shaft. The direction of the feed is reversed again by similar mechanism when the rivet at the right hand end of the ribbon actuates lever B.

The Governor used for maintaining steady and uniform speed, and the circuit connections, are exactly the same as for the Teletype No. 1A.

(*To be continued.*)

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

TELEPHONES AND WIRE MILEAGES, THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 31ST MARCH, 1928.

No. of Telephones owned and maintained by the Post Office.	Overhead Wire Mileages.				Engineering District	Underground Wire Mileages.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
579,919	536	4,059	51,819	164	London.	23,936	66,027	2,182,942	106,785
73,040	2,125	21,536	63,966	1,531	S. Eastern	3,904	45,640	184,712	13,785
77,205	4,344	30,485	53,910	2,655	S. Western	19,352	11,257	139,272	59,018
60,138	6,090	37,649	57,158	4,759	Eastern	22,418	35,476	101,514	74,265
93,826	8,755	44,917	57,317	3,498	N. Mid.	24,637	51,426	237,059	119,626
74,684	4,791	29,416	69,671	4,150	S. Mid.	13,298	22,330	168,532	88,843
57,011	4,671	29,387	51,444	2,771	S. Wales	6,120	25,962	114,617	71,551
100,650	8,024	26,433	48,863	4,182	N. Wales	13,431	41,101	258,464	60,868
153,882	1,528	16,489	42,865	2,502	S. Lancs.	13,422	77,584	459,024	46,327
90,562	6,195	30,784	46,298	3,103	N. East.	11,324	44,590	154,908	67,518
62,466	3,539	23,843	37,052	2,187	N. West.	8,110	32,756	154,908	37,163
46,030	2,511	16,100	24,445	2,547	Northern	4,687	14,776	102,655	51,190
20,932	4.686	8,313	13,703	492	Ireland N.	133	2,306	37,276	1,208
63,652	5,472	25,373	36,584	1,461	Scot. East	3,664	12,212	144,398	47,674
85,840	7,332	24,155	42,695	913	Scot. West	12,116	24,489	217,421	34,857
1,639,837	70,599	368,939	697,790	36,915	Totals	180,552	507,932	4,719,708	880,678
1,605,601	70,769	366,530	690,505	37,957	Figures as 1927. at 31st Dec.	176,404	498,940	4,604,092	876,339

TELEPHONES

BISHOPSGATE AUTO. EXCHANGE.

BISHOPSGATE Exchange, in Little Pearl Street off Commercial Street, was the second London local automatic exchange to be opened for traffic. 1,300 subscribers were transferred on March 3rd and a further 3,600 on March 10th.

The equipment is similar to that installed at Holborn, but unlike Holborn building, which holds both Tandem and Holborn, there is only one Exchange in the building.

The telephone equipment was manufactured and installed by the Automatic Telephone Manufacturing Co. Ltd., of Liverpool.

The plant is of Strowger type, with equipment for 8,000 lines, and ultimate capacity for 10,000 lines. The plant includes:—

195	directors on 14 boards.
4773	selectors on 32 boards.
56	senders on 7 racks.
960	C.C.I. relay sets on 8 racks.
78	coders on 2 boards.
36	line switch units, ordinary type.
45	,, ,, ,, P.B.X. ,,
1000	junction relay sets.

The plant is located on two floors; the first floor contains the main frame, test desk, 70 line switch units, power plant, batteries. The second floor contains 11 line switch units and all selector boards, coders, senders, junction relay groups, etc.

The power plant includes two 25-cell (50 volt) 8,000 amperehour batteries (at 9 hr. rate) made by the Chloride Electrical Storage Company: and a 7-cell Counter E.M.F. battery to carry 94 amperes. Messrs. Newton Bros. (Derby), Ltd., supplied the two charging machines, each set comprising a 480v D.C. motor direct coupled to a 1,600 ampere 57 volt D.C. generator. The power board allows for either set to charge either battery or to supply current to the exchange *via* a choke coil in parallel with a battery.

The distribution of power to the various boards and racks is done from three feeder fuse boards. One is located at the power board: one is located on the 2nd floor centrally placed as regards selector boards, and the third is located on the 2nd floor near the junction apparatus.

There is a separate P.B.X. fuse panel, with capacity for 800 fuses, placed near that portion of the main frame where the Prot. H.C. & F. for P.B.X. power leads are located. The manual fuseboard, on which P.B.X. fuses usually are placed, is on the 2nd floor. It was more economical to take the 30v P.B.X. supply lead direct to the fuse panel and have very short switchboard cabling to protectors than to carry the 30v lead upstairs and have long switchboard cabling down to the main frame.

Fig. 1 shows part of the first floor. The meter rack is made in two parallel racks, the nearer one having capacity for 300 meters per bay and the farther one having capacity for 600 meters per bay. The routine test strips for subscribers' meters are clearly shown at right hand of each bay. Beyond the meter racks are line switch units. It will be noticed that the main girders are not totally enclosed in concrete. The height of the building was reduced a few inches by adopting this course, as the depth of the concrete to cover rivet heads was dispensed with.

The manual switchboard on the fourth floor has 3 suites as seen in Fig. **2**.

There are 38 A positions; 18 B positions in the suite by the wall and 7 B positions in the centre of the room. The supervisors desk is seen by the pillar; the meter cabinet contains (*a*) the A operators' position meters worked from a peg count key when required on A positions; (*b*) the B operators' position meters worked automatically from the Pos. apparatus in the auto. room, and (*c*) meters on incoming junctions associated with the key sender positions worked automatically when the release magnet of the selectors on these incoming junctions is energised. Meters are provided at the rate of one per half shelf (*i.e.*, capacity 10 switches) of 20 selectors.

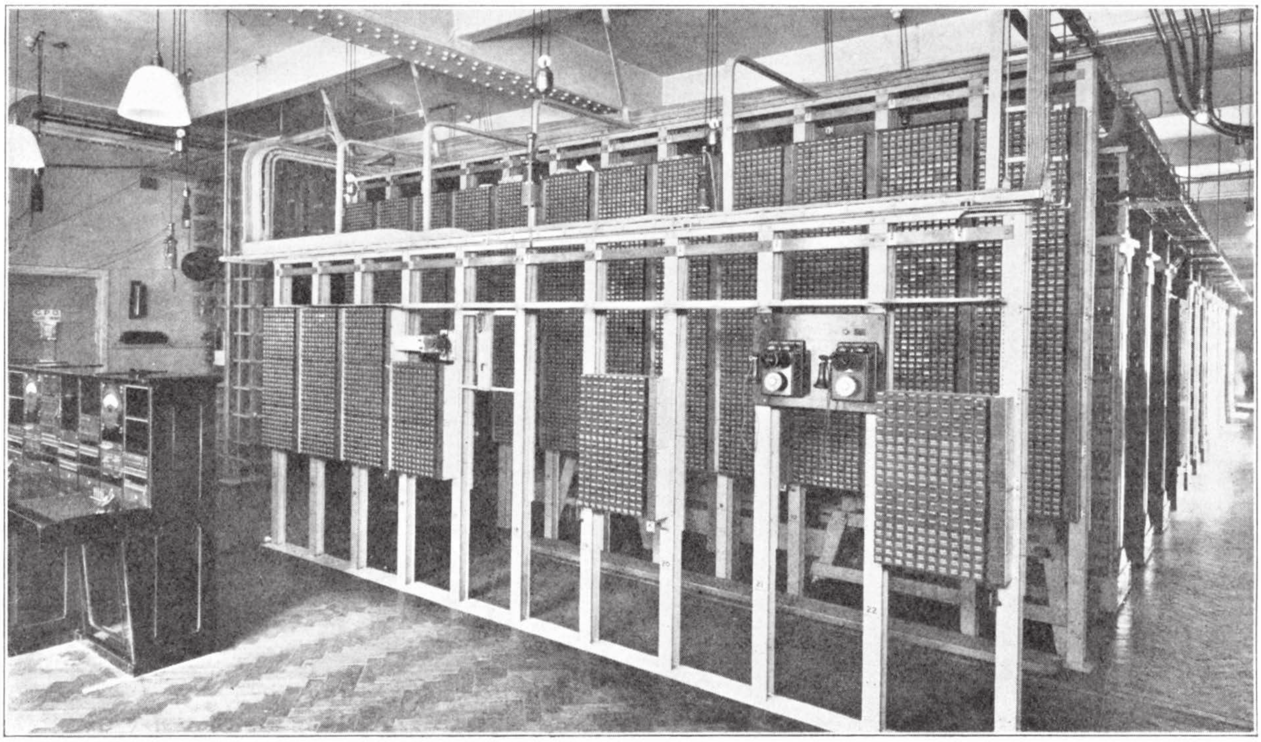


FIG. **1**.—BISHOPSGATE EXCHANGE. PART OF FIRST FLOOR.

The circuits and apparatus used at Bishopsgate are the same as used at Holborn and the disposition of apparatus on racks is the same.

In order to test the plant continuously, various automatic routiners have been provided. In themselves, these routiners are fairly complicated mechanisms and contain a considerable quantity of apparatus; for instance, the director routiner contains:—

88 relays.
21 rotary line switches.
15 lamp jacks each for 20 lamps.
1 fuse panel capacity 22 fuses.
10 minor switches.
10 strips of lamp jacks (10 per strip).
30 tag blocks.
6 tag strips.
14 mountings each of 6 lever keys.

Routiners are also provided for testing automatically, Coders, 1st Code Selectors, Senders, C.C.I. repeaters and Junc. Relay Sets. The times taken by these routine testers are approximately as follows:—

Director Routiner takes approximately 1½ mins. for each Director. If the Forced Release test is cancelled, this is reduced to 50 secs. Due to the busying ahead feature, there is no waiting time for the Director to become disengaged.

First Code Selector Routiner takes approximately 2 mins. for each Selector. If the two Forced Release tests are cancelled, the time is decreased to 40 secs. The average waiting time of 1¼ mins. in busy period of day is not included in the test times.

Coder Routiner takes approximately 30 secs. for each Coder, plus average waiting time of 9 secs. in busy period of day.

C.C.I. Repeater Routiner takes approximately 20 secs. for each Repeater, plus the average waiting period for the Repeater to become disengaged. This will vary according to the time of day that the test is made and may be 0.60 seconds.

Sender Routiner takes approximately 20 secs. to test each Sender, plus average waiting time of 6 secs. in busy hour.

Keysender "B" Position Apparatus Junc. Relay Set Routiner takes approximately 35 secs. to test each Junction Relay Set. Busy Relay Sets are passed without being tested and without any alarm being given.

The writer is indebted to the Automatic Telephone Company for the photographs.

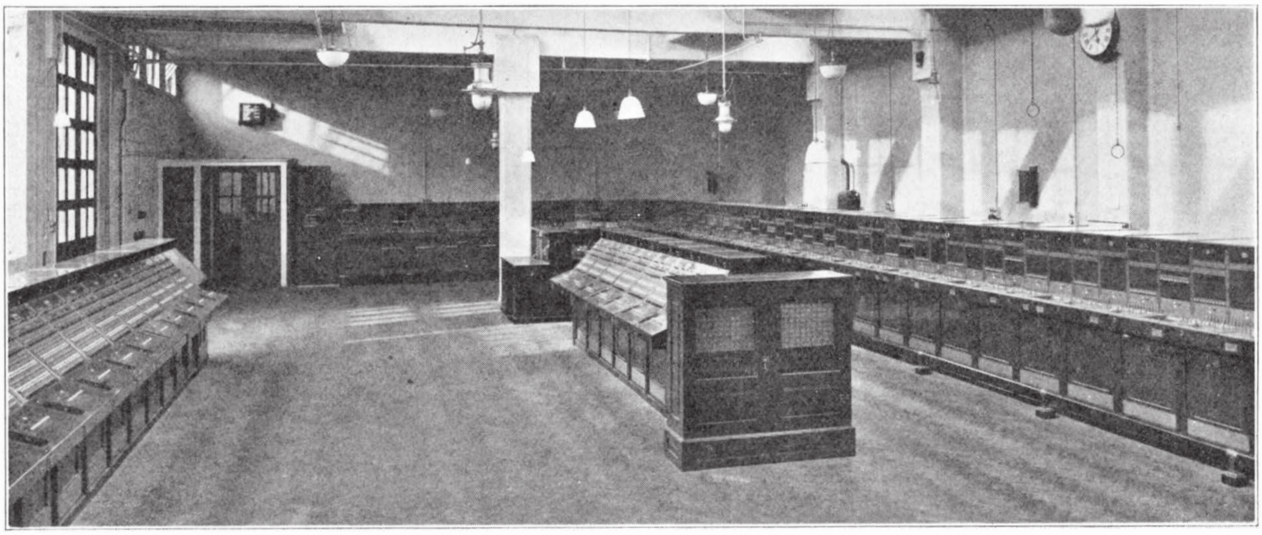


FIG. 2.—BISHOPSGATE EXCHANGE. CORDLESS "B" AND "A" AUTO. MANUAL POSITIONS.

LONDON AUTOMATIC SYSTEM.

MANUAL SERVICES.

H. MORTIMER, E.-in-C.'s Office.

UP to the present an article has not appeared in this Journal in connection with the manual services for Trunks, Toll, Telegrams and Directory Enquiry, which have been adopted as a standard by the British Post Office for Director areas.

It is not proposed to explain the use of these services as they are well-known, but it will be realized that it is necessary for some code or numbers to be dialled by automatic subscribers or operators to gain access to them *via* the automatic switching plant.

Three lettered codes as follows are therefore dialled:—

Trunks	TRU
Toll	TOL
Telegram	TEL
Directory	DIR

It will be noticed that the code corresponds to the first three letters of the service required, so that the subscribers should not experience any difficulty in remembering them.

To route the calls *via* the automatic switching plant, it is necessary to translate the codes dialled into their numerical equivalents of the level of the Code Selector Switch from which they are routed; for example, at Holborn Automatic Exchange and Tandem Exchange, the code translations are as follows:—

Service	Holborn	Tandem
TRU	38	02
TOL	32	04
TEL	312	01
DIR	503	03

It will be realised of course that the routing can take place *via* any level of 1st, 2nd or 3rd code switches, and that they would not necessarily be the same levels in all exchanges.

The traffic facilities to be given on these four services vary somewhat, and the following schedule clearly indicates the service requirements in this respect:—

Service	Circuits to which automatic subscribers have access.	Circuit to which operators have access.
TRU	Non-metering Non-holding	Standard Supervision.
TOL	Non-metering, holding, flashing-in by subscribers.	do.
TEL	Metering, non-holding.	do.
DIR	Non-metering, holding, flashing-in by subscribers.	do.

To obtain the foregoing facilities, it has been necessary to design special circuits for the relay sets inserted in the respective junctions. The diagram number referring to the relay sets will be seen on the routing diagrams reproduced with this article.

Attention is drawn to the fact that where standard supervision is desired, it is not possible to give non-metering conditions, therefore, separate groups of circuits have to be provided.

The following shows the different groups of circuits that have been provided in the London Automatic System to meet all the varying conditions.

Trunks—

(i) Automatic subscribers.
(ii) Automatic manual board.
(iii) Manual exchanges which circulate their traffic *via* Tandem.
(iv) Automatic subscribers *via* Tandem.

Toll—

(i) Automatic subscribers.
(ii) Automatic manual board.
(iii) Manual exchanges which circulate their TOL traffic *via* Tandem.

Telegrams—

(i) Automatic subscribers
Automatic manual board } Common group.

(ii) Automatic subscribers
Automatic manual board
Manual exchanges } Common group for traffic circulated *via* Tandem.

Directory—

(i) Automatic subscribers
Automatic manual board } Common group *via* Tandem.

(ii) Manual exchanges *via* Tandem.

Owing to circuit complexities it was decided that separate groups should be provided for automatic subscribers and auto. manual board to Toll and Trunk respectively. With regard to the direct circuits from the auto-manual boards to Toll and Trunk exchanges, in order to obtain standard supervision it has been necessary to insert a relay set in each circuit, owing to the dry loop condition which exists in the cord circuit (diagram A.T. 812) on the automatic manual boards fitted within the 5 miles area. Outside the 5 miles area, the cord circuit (diagram A.T. 1704) fitted on the manual board provides for standard supervision. It has also been decided, with regard to Toll calls from auto.-manual boards, that the control of the call shall be placed with the A operator at the auto.-manual board; therefore, these circuits terminate on the through clearing positions in the Toll Exchange. The calls originated by an automatic subscriber will be controlled by the Toll operator, and in this case the circuits terminate on a control position at Toll.

It will be seen that it is necessary to provide these different combinations of circuits to cater for the four services in the London Area.

ROUTING OF CALLS.

From a perusal of the diagrams showing the routing and circuit diagram numbers referring to the equipment concerned in a through call from any source, it will be seen that for the manual exchange end Diagram C.B. 904 has been quoted. This must be taken as typical only.

The method adopted by the distant manual exchange desiring to obtain Trunks, Toll, Telegram or Directory Enquiry is as follows:—

The distant A operator passes the demand over an order wire to the Tandem B operator for Trunk, Toll, Telegram or Directory as the case may be. The key sender B position operator at Tandem then keys up the three letter code demanded, the call then being routed by the sender *via* the Tandem first and second Code selector switches and relay set (if concerned) to the respective service.

In the case of a subscriber, the desired code is dialled into the Director switch in the automatic exchange. The call is then routed (after the Director has carried out the translation), *via* the first, second or third code selector switches in the originating exchange to the respective service, or *via* the first code switch in the originating exchange, to the incoming first Tandem switches in Tandem exchange, where the call is then routed direct from the second code selector levels.

Should the auto-manual board require any of the four services, the operator can gain access to Toll or Trunk by plugging into the corresponding outgoing junction multiple, or, in the case of Telegrams and Directory, by dialling the code required *via* the first code manual selector switches. This gives access to Telegrams and Directory *via* the same group of circuits to which the subscribers have access. For further particulars of the routing scheme reference should be made to the standard trunking diagrams referring to each exchange.

CIRCUIT DESCRIPTIONS.

With regard to the circuit diagram numbers quoted, it is not proposed to explain the circuit operations in detail (as this would take too much valuable space), but to indicate only the salient features of the relay sets that are inserted in the junctions, between the Automatic or Tandem exchanges to the four services. The circuits at the originating end follow standard practice; therefore, no circuit description is necessary as these are well known.

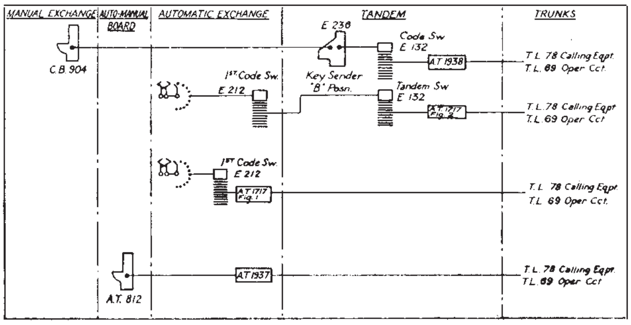


FIG. **1**.—TRUNKS.

TRUNKS.

Calls routed via Tandem from Manual Exchange.

Relay Set Diagram A.T. 1938 is inserted for the purpose of giving standard supervision to the distant operator. It also provides for guarding the P bank contact after the manual exchange operator has cleared, until the trunk operator clears; this feature is provided to prevent following-on calls from being lost.

Calls routed via Tandem from Automatic Subscribers.

The Relay Set A.T. 1717, Fig. **2**, is provided in the circuit between the outgoing level at Tandem exchange, and the Trunk exchange. Its function is to provide holding facilities for the Tandem selector switches until released by the calling subscriber and also to guard the P wire bank contact after the subscriber has cleared until the Trunk operator clears the connection.

Calls routed from Auto-Manual Board.

In this case, the Relay Set A.T. 1937 is inserted to provide standard supervision to the auto-manual board A operator, and also to maintain the visual engaged signal lamp on the auto-manual board after the A operator has cleared, until the connection is cleared by the Trunk operator. It should be noted that a Relay Set A.T. 1937 is only necessary in the junction circuits from the auto-manual board within the five miles area, owing to the " dry loop " condition of the calling cord circuit. Outside the five miles area, the cord circuits are designed to give either wet or dry loop conditions, therefore relay sets are not necessary under these conditions.

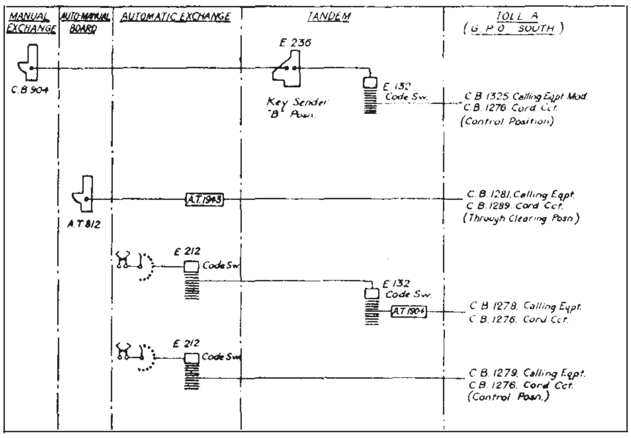


FIG. 2.—TOLL.

TOLL.

Calls routed via Tandem from Manual Exchanges.

No relay set is necessary in these circuits, as the calling equipment and cord circuit at the Toll exchange provide for standard supervision being given to the distant A operator.

Calls routed from Auto-Manual Board.

The conditions quoted under the same heading for Trunks apply to this circuit.

Calls routed via Tandem from Automatic Subscribers.

The Relay Set A.T. 1904 caters for the same conditions as those under the similar heading for Trunks.

Calls routed direct from Automatic Exchanges from Automatic Subscribers.

A relay set is not necessary in this case, as the second or third code selector switches are held by the forward earth from the first code selector switch.

It should be stated that holding conditions are provided in the latter two groups so that the subscribers can flash in the Toll operator without breaking down the train of automatic switches.

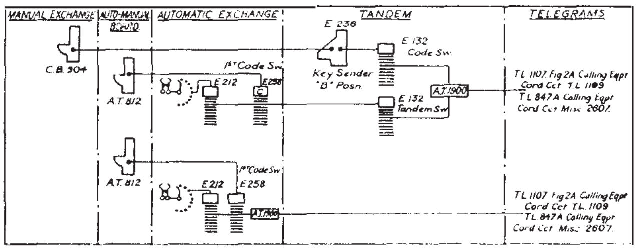


FIG. 3.—TELEGRAMS.

TELEGRAMS.

Calls routed either from an Automatic Exchange or *via* Tandem Exchange use a common group of circuits in each case because registration of the subscriber's meter and also standard supervision is desired on these calls. Both these conditions are obtainable, due to the reversal which is brought about in the relay set when the telegram operator answers. Relay Set A.T. 1900 provides for the reversal, and also guards the " P " bank contact against intrusion after the calling subscriber has cleared, until the telegram operator clears.

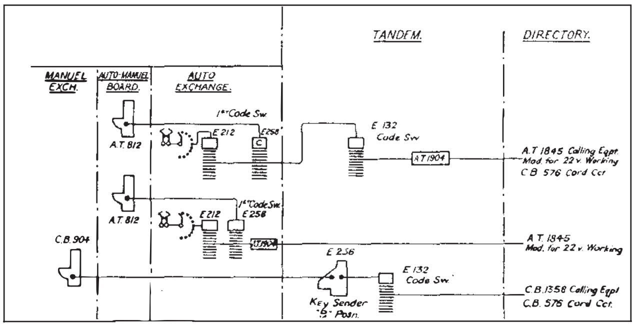


FIG. 4.—DIRECTORY.

DIRECTORY ENQUIRY.

Calls routed from Automatic Subscribers and Auto-Manual Boards direct or via Tandem.

Relay Set A.T. 1904 in this case provides holding facilities which enables the calling subscribers to flash in. It should be stated that full standard supervision is not given on the calls routed from the auto-manual board, owing to the fact that the group of circuits used are the same as those used by the automatic subscribers, and standard supervision and non-registration cannot be given on the same group of circuits. The reason for using the common group is, that the traffic from the auto-manual board will be very small indeed, and would not, therefore, justify a separate group of costly junctions being provided for this purpose.

Calls routed via Tandem from Manual Exchanges.

A relay set is not required in these circuits, as the junction relay group of the key sender B equipment provides the hold forward condition, which enables the Tandem first and second Code selector switches to be held in the operated condition, also, the answering equipment at Directory provides for standard supervision to be given to the originating A operator.

The numbers quoted on the circuit diagrams refer to the particular apparatus concerned, from which full circuit conditions can be obtained.

It is thought that the foregoing remarks, together with the routing diagrams, will enable those interested, to obtain a knowledge of the somewhat complex trunking scheme required for these four services.

MECHANICAL ORDER-WIRE OPERATION.

A METHOD OF HANDLING TRAFFIC FROM MANUAL TO AUTOMATIC EXCHANGES.

D. A. Christian (of Siemens Bros & Co., Ltd.).

Present Methods of Operation.

THE use of an order-wire for handling the traffic between two manual exchanges is well known and has for long proved the most efficient and economical method of manual to manual operation. The outstanding advantages that the order-wire method of operation provides are speed of operation, particularly with respect to the time taken by the " A " operator to handle the call, and simplicity in the junction circuit arrangements necessary. The short time taken by the " A " operator to handle a call is chiefly due to the junction assignment being given from the " B " end, thereby relieving the " A " operator from the necessity of searching for a free junction. The simplicity of the junction circuit arrangement is due to the use of the order-wire for initiating the call, only the clearing signal being controlled over the junction.

When the incoming exchange is converted to automatic working a new set of conditions is obviously met, and at present one of the two following methods of operation is usually adopted. Dials are provided on the " A " positions and the " A " operators have to search for a free junction and dial the necessary trains of impulses to set the automatic switches. This method may be looked on as adopting automatic principles of operation at the manual exchange, in that a search is made followed by transmission of impulses: it is obviously uneconomical in " A " operators' time and is quite unsuitable where the junction traffic is heavy. The alternative method is to retain the services of " B " operators at the automatic exchange and provide cordless " B " positions there. This method may be looked on as adopting manual principles of operation at the automatic exchange and while maintaining the efficiency of the " A " operators, it incurs considerable expense at the " B " end.

Fundamental Considerations Involved in the Problem.

On consideration it will be realised that the completion of a manual to automatic call comprises two operations which are to a great extent distinct, and that several methods of operation are in each case available. These operations and the possible methods of accomplishment are indicated in the following table:—

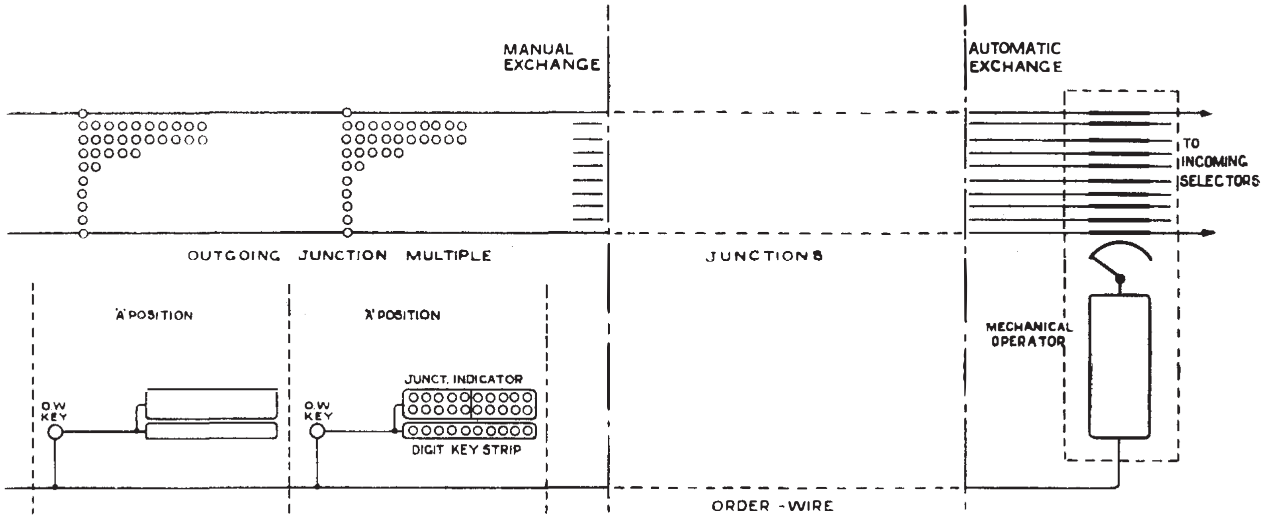
(1) *The Selection of the Junction.*
  - (*a*) Click tests made by the " A " operator, with or without group engaged test.
  - (*b*) Visual engaged signals.
  - (*c*) Individual jacks for each operator with junctions automatically selected by junction finders.
  - (*d*) Demand and assignment, as for example, over an order-wire to a " B " operator.

(2) *The Transmission of the Number Required*
  - (*a*) Dialling.
  - (*b*) Digit-key Strip.
  - (*c*) Verbal communications with a " B " operator.

The development of any scheme for handling manual to automatic traffic is mainly a matter of combining the particular methods chosen for these two operations. The arrangements about to be described combine methods (*d*) and (*b*).

THE ADAPTION OF ORDER-WIRE WORKING TO AUTOMATIC CONDITIONS.

In manual order-wire operation, the " A " operator depresses the particular order-wire key: passes the required number to the " B " operator verbally: receives a junction assignment also verbally: and connects the calling cord to the assigned junction. Simultaneously the " B " operator connects the assigned junction to the required number in the multiple. Mechanical Order-wire Operation is based on precisely the same principles but employs what may be termed a mechanical or automatic " B " operator at the automatic exchange. The mechanical-operator, sometimes termed a decoder-sender, consists of a selector type switch and an associated controlling circuit consisting of relays and preselectors. Manifestly, such an apparatus unit cannot respond to a verbal request from the " A " operator, nor can it verbally assign a free junction: the " A " operator is therefore provided with a digit-key strip by which the required number can be signalled and a visual number indicator on which the assignment can be received. A diagrammatic representation of the condition so far considered is shown in Fig. 1.



ELEMENTARY DIAGRAM
SHOWING PRINCIPLE OF MECHANICAL ORDER-WIRE OPERATION

FIG. 1.

Considering this diagram, it will be seen that conditions exactly similar to manual order-wire working are obtained. The " A " operator, by depressing the order-wire key, can signal to the mechanical-operator the required number by means of the digit-key strip: the mechanical-operator can select a free junction and by signals reverted over the order-wire can indicate the number of the junction on the visual indicator and the mechanical-operator can extend the junction assigned to the required number by sending out the necessary trains of impulses to the automatic equipment.

In the above simple consideration two points have, however, been neglected, and the arrangement requires extension to cover these. In the first place it is clear that while one " A " operator is using the order-wire for signalling, it must be guarded from interference by other " A " operators. This is easily effected by introducing a testing or coupling relay between the order-wire key and the order-wire and arranging the circuit so that when the relay of one position is operated the relays of other positions are unable to operate even if their order-wire keys are depressed. In the second place the mechanical-operator will take much longer to set up the connection through the switches of the automatic equipment than a manual " B " operator will take to plug into the required number in the multiple. To meet this condition it is necessary to provide a number of mechanical-operators to serve the order-wire, these taking duty in rotation. The condition now arrived at is shown in Fig. **2**. The necessary junction relay equipment to convert from manual to automatic signalling is indicated in this diagram and the junction indicator is shown in an alternative position in the panel instead of on the keyshelf in front of the digit-key strip.

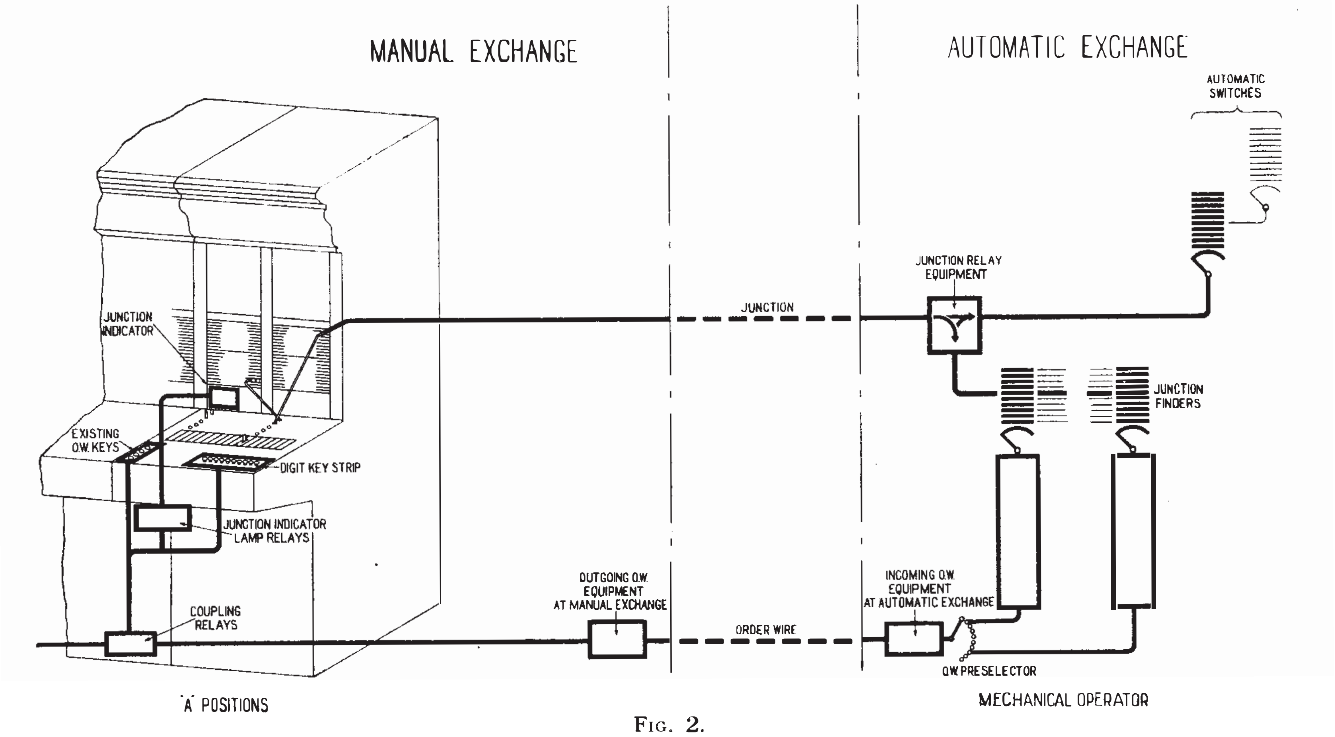


Fig. 2.

The elements of the system having now been explained, a more particularised and detailed description of the method of operation may be given.

Under normal conditions, that is, when no calls are being set up, each mechanical-operator preselects a disengaged junction and couples itself thereto by means of its junction-finder switch. This switch may be of any convenient type according to the number of junctions required: that shown in the diagram is an ordinary two-motion switch provided with the special rotary release magnet used on the Siemens' P.B.X. Final Selector circuit, which enables the wipers to search over all levels successively until a free contact is found. The order-wire preselector also preselects and couples the order-wire to a free mechanical-operator.

On receiving a call for the automatic exchange in question, the " A " operator depresses the corresponding order-wire key. This action tests the order-wire circuit, and if the latter is free, gives the operator the sole use of it as long as the key is depressed.

The operator now keys up the required number on the digit-key strip and each digit is instantaneously transmitted over the order-wire and stored in the selected mechanical-operator.

Immediately on release of the digit-key used for the units digit, the code corresponding to the number of the junction to which the mechanical-operator is coupled is transmitted back over the order-wire and appears on the junction-indicator on the " A " position. The operator having noted the junction number then releases the order-wire key and frees the order-wire for further use. On the release of the order-wire key the junction number is extinguished.

A suitable time is now provided during which the operator can take the junction by plugging into the outgoing junction jack. Should the operator not take the junction, then on the expiry of this period the whole connection is released and the switches return to normal without the called subscriber being rung. Assuming the operator has taken the junction, the mechanical-operator completes the setting up of the connection in the automatic exchange. As soon as this is done it disconnects itself from the junction and its finder again commences to search. The junction is now switched straight through to the automatic switches and the connection is dependent on the presence of the calling plug in the outgoing junction jack.

During conversation full normal supervision is given on the " A " operator's supervisory lamp and on reception of the clearing signals the operator takes down the connection in the ordinary way and the switches in the automatic exchange return to normal.

If, when the operator depresses the order-wire key, the order-wire is already engaged or if there are no free mechanical-operators available, a tone is heard in the operator's receiver. In these circumstances the order-wire key may be held depressed, and as soon as connection with a free mechanical-operator is made, the tone will cease and the call can be set up. Or, if the group of junctions is so large that it requires the use of two or more order-wires, the second or later choices may be tried, just as in manual practice. Should the operator realise that she has operated the digit-keys incorrectly, she can correct the mistake in a quite natural manner, namely, by releasing the order-wire key, re-depressing it and setting up the number again.

For the sake of clarity it has been inferred in the above description that the digit signals are stored in the mechanical-operator until the " A " operator takes the junction. Actually the impulse train corresponding to the first digit is transmitted as soon as the digit is received and each of the remaining trains, except the units train, as quickly as possible after the reception of the corresponding digit. The transmission of the units train is made dependent on the " A " operator taking the junction and, if necessary, is held up until she does so. By this means the call is set up with the minimum delay while at the same time it is ensured that the required line is not rung until the junction is taken.

Since the method of operation follows so closely to existing manual order-wire operation, there is no alteration or modification whatever required to the outgoing junctions or outgoing junction multiple nor to the " A " position cord circuits, nor is it necessary to provide visual engaged lamps or group engaged tests in connection with the outgoing junction multiple. Also the whole outgoing junction multiple remains fully available to all the " A " operators. A further feature is that all the automatic equipment is at the automatic exchange where the battery voltage and other arrangements are most suited to its operation. The equipment at the manual exchange, with the exception of the digit keys and junction indicator, consists entirely of relays, for the operation of which the manual exchange power plant is, of course, quite suitable.

Description of the Equipment Required.

The equipment required at the manual exchange for mechanical order-wire operation is very simple.

Each position is equipped with a digit-key strip and a visual number indicator capable of exhibiting two figures. These may be of any convenient type as found most suitable for the " A " positions to be equipped. Two types of digit keys are shown in Fig. **3**. The longer type will be familiar as the type of strip standardised for use on cordless " B " positions, while the staggered type has been developed for use when the space available on the " A " positions is limited. The junction number indicator is arranged in a form similar to the well-known code call indicator display, except that it shows only two figures. It may be arranged in the panel equipment or on the keyshelf where space permits. The only other item required on the position is the order-wire key itself, which being of the ordinary type with two make contacts, will in almost all cases already exist.

All the other equipment at the manual exchange consists of relay groups, which are provided as follows: One group per "A" position, consisting of thirty relays which control the indicator lamps and the order-wire testing circuit: one relay per position per order-wire for coupling the position apparatus to the particular order-wire required: and one relay per order-wire per exchange associated with the order-wire itself.

It may perhaps be emphasised that the digit-key strip, the junction-indicator and the position relay group are common to any number of order-wires and need no alteration whatever, no matter how many further order-wires may be converted to mechanical operation.

The chief item of equipment at the automatic exchange is, of course, the mechanical-operators and these may vary somewhat in size and appearance according to the size of equipment required. A rack of these circuits is shown in Fig. 4, from which the general appearance of a typical equipment may be obtained.

The junction relay equipments at the automatic exchange are pure relay equipments with circuits very similar to the ordinary incoming junction circuit, the precise circuit required depending, of course, on the type of manual and automatic equipment with which it has to

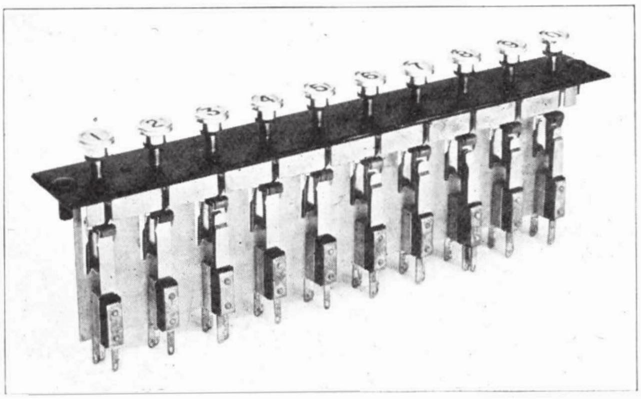


FIG. 3.

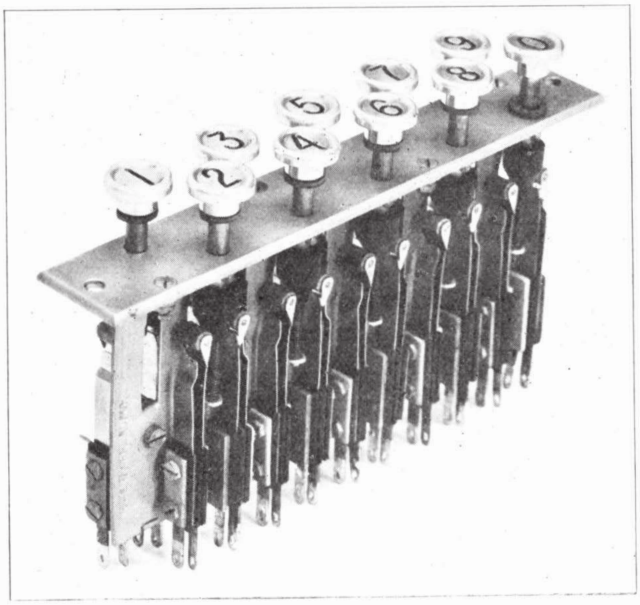


FIG. 3.

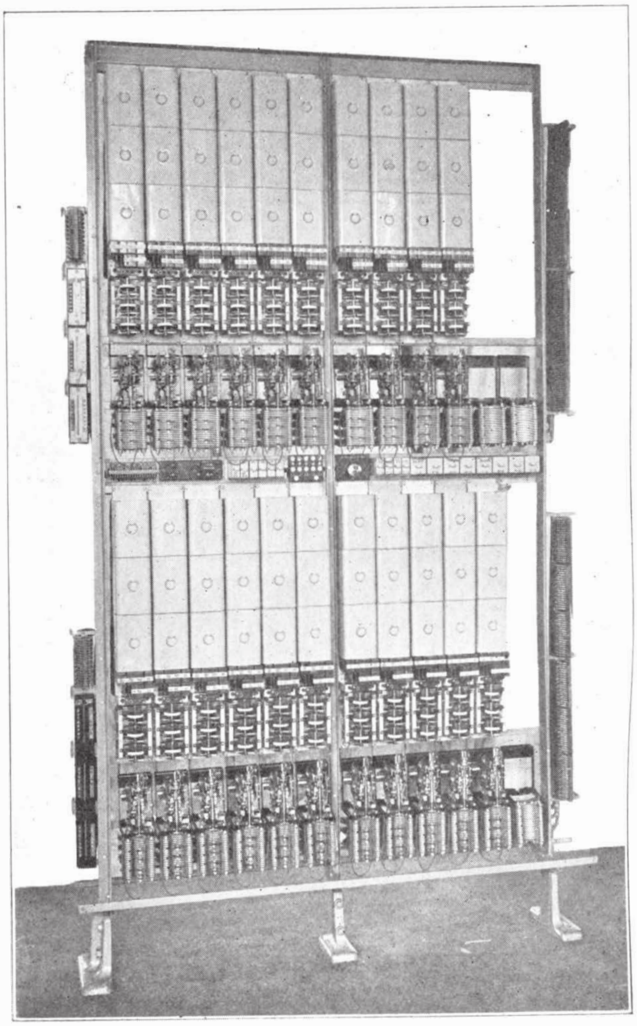


FIG. 4.

operate. This circuit also provides the point at which the mechanical-operator makes connection with the junction.

The order-wire preselector is a simple preselecting circuit and needs no special description.

CIRCUITS.

A full description of the circuits used in this method of operation is considered quite unnecessary to a general understanding of the system and would indeed occupy more space than is available. The following elementary diagrams and description may, however, be appreciated by those interested in circuit design and will at least indicate the principle of operation utilised.

Fig. 5 shows a general circuit outline of the arrangements. In this diagram no attempt is made to show the detailed circuit operation, most of which is quite conventional in character and is of interest only to those operating the equipment.

Referring to the diagram, it will be seen that the order-wire proper consists of four wires. At the manual end these, together with two further wires, are multipled to all the " A " positions as in manual practice, although since the position relay equipment is probably most conveniently mounted on special racks, it does not follow that these six wires are actually taken round the manual sections. At the automatic end the order-wire terminates on the order-wire preselector which connects it through to a mechanical-operator.

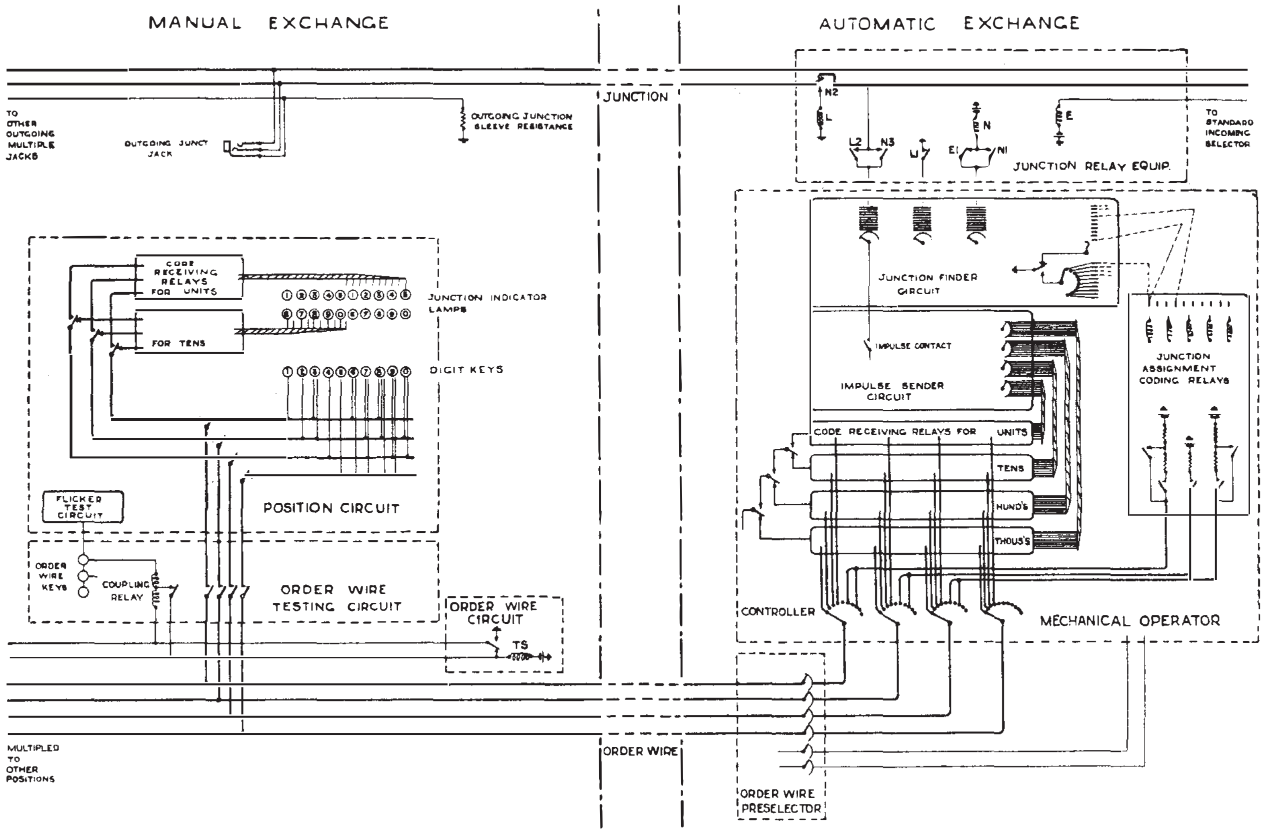


FIG. 5.

When the " A " operator depresses an order-wire key the flicker test circuit is set in operation and under control of this circuit, the precise operation and functions of which are described later, the particular order-wire is tested and the coupling relay connects the four order-wire conductors through to the position if the order-wire is free. The change-over relay contacts are at present in the unoperated position and the order-wire is therefore connected directly through to the digit-keys. Assuming that a free mechanical-operator which has preselected a free junction is available at the automatic end then a relay, not indicated in the diagram, operates and disconnects the busy tone from the " A " operator's receiver. The operator now depresses the required digit-keys one after the other and each key connects earth to one or more of the order-wire conductors in definite combinations.

The controller switch in the mechanical-operator steps on the release of each digit-key, thus distributing the digit codes to the thousands, hundreds, tens and units code receiving relays.

The transmission of impulse trains dependent on the digits received is controlled by the impulse sender circuit. The diagram indicates how each digit is in turn connected up to the banks of the sender-switch. The details of the impulse transmitting circuit are too involved to indicate clearly in the diagram, but contain no point of particular interest to this method of operation. The junction relay equipment shown is suitable for a Siemens No. 16 type automatic exchange and in this case the impulses are transmitted *via* the " A " line to the junction circuit and thence to the automatic switches.

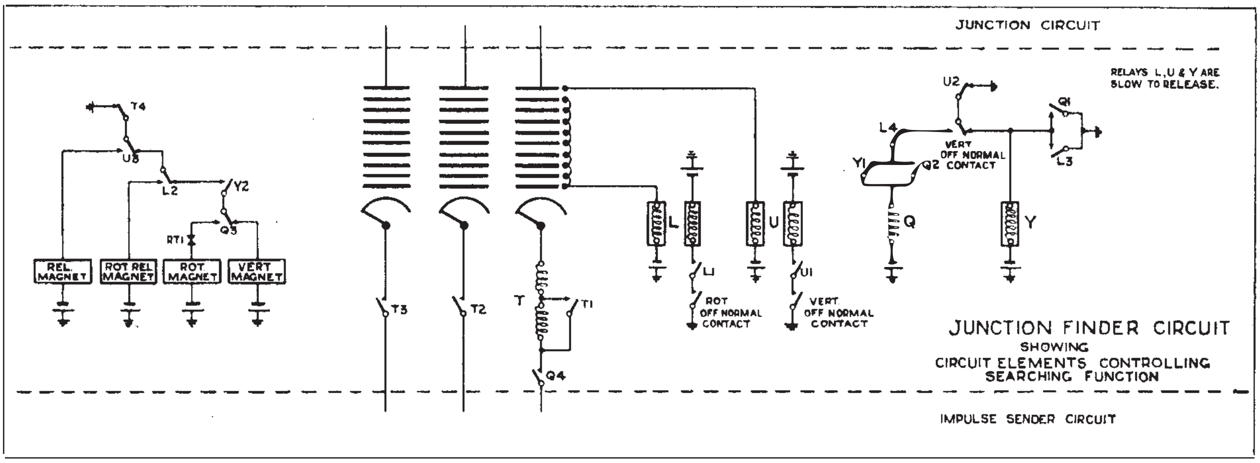


Fig. 6.

Immediately the units digit has been received by the mechanical-operator the controller steps on to the first code transmitting position, the junction assignment circuit is now brought into operation and a certain combination of the coding relays is operated dependent on the vertical position of the junction-finder switch and the contacts of the operated relays connect definite potentials to the order-wire conductors. The change-over relay circuit at the manual position also changes over at the release of the units digit-key and the code thus transmitted is received on the tens set of code receiving relays at the manual end. These relays lock up and the associated lamp in the junction indicator lights. The controller now steps to the second transmitting position and the action is repeated except that the assignment coding relays are now dependent on the rotary position of the finder switch. The number of the junction assigned is thus shown on the junction-indicator and the " A " operator now releases the order-wire key and plugs into the assigned junction. Although this operation takes some time to describe, it should be realised that the action takes place so quickly that the assignment is shown almost instantaneously after the release of the units digit key.

Meanwhile impulses are being transmitted by the mechanical-operator to the junction and thence to the switches in the automatic exchange from the impulse contact *via* the first wiper of the junction finder switch and contact N3 in the junction circuit.

On plugging into the junction the " A " operator operates relay L in the junction relay equipment. Contact L1 signals the fact to the mechanical-operator and thus permits the units impulse train to be sent and the required line to be rung. On the completion of the units train the mechanical-operator releases itself from the junction by opening the circuit of its third wiper, thus releasing relay N and connecting the junction through and leaving the connection entirely dependent on the presence of the plug in the outgoing junction jack. In the circuit arrangements indicated, which are suitable for use with an automatic exchange of the Siemens' No. 16 type, the connection is actually held by the battery on the " B " wire holding the line relay in the transmission bridge which is situated in the incoming selector: the incoming selector in turn holding relay E in the junction relay equipment and thus at E1 marking the junction engaged to other searching junction-finder switches. With automatic equipments using circuits based on other prnciples the junction auxiliary equipment circuit will differ from that shown and may require a transmission bridge to convert the manual signals to the type used in the automatic exchange.

After the mechanical-operator is released the junction finder proceeds to search, if necessary, level after level, for another free junction and having found one stops thereon and waits until it is again taken into use by the order-wire. The circuit control for effecting this searching action is shown in Fig. **6** and the action is as follows:—

On reaching the last (eleventh) contact in a level relays T and L operate in series: T4 cuts the drive circuit to the rotary magnet: L locks through L1 and the rotary off-normal contact: L2 connects up the rotary release magnet and L3 operates relay Y. Relay Q is released by L4: Q4 releases relay T: T4 closes the circuit of the rotary release magnet and the selector wipers are returned to rotary normal (without, however, the selector shaft being dropped to vertical normal). The rotary off-normal contact opens on rotary normal being reached and relay L releases: L2 closes the circuit of the vertical magnet and the wipers are stepped up to the next level. Relay Y now releases and at Y1 operates relay Q: Q3 prepares the circuit of the rotary magnet: Q1 again operates relay Y which at Y2 closes the circuit of the rotary magnet and the search again proceeds. On reaching the last contact of the " O " level, relay U is operated instead of relay L and by a similar action which will be readily traced from the diagram the wipers are completely released to vertical normal and then stepped up to the first level and the search again proceeds.

The order-wire testing circuit, including the flicker test circuit, is shown in Fig. **7**. By means of the flicker test circuit double connections on the order-wire are made a practical impossibility. The principle of action is that the testing relays are designed so that two cannot operate in parallel: the result of this, without the flicker test circuit, would be that the operators would lock each other off the order-wire if more than one operator was waiting with her order-wire key depressed for the order-wire to go free. The flicker test prevents this state of affairs occurring as will be seen from the following description:—

ORDER-WIRE TESTING CIRCUIT
SHOWING FLICKER TEST

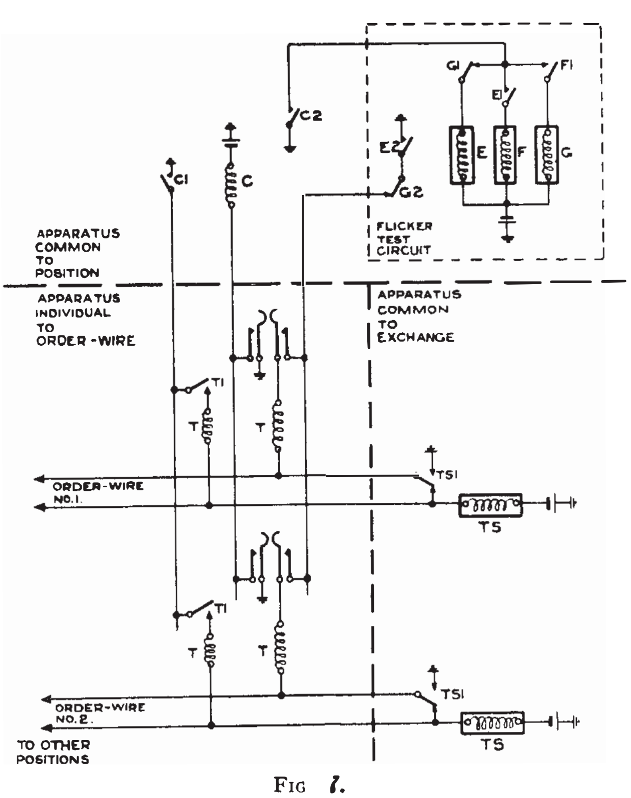


Fig 7.

When the order-wire key is depressed the circuit of relay T is not directly closed as it is still open at E2. Relay C, however, operates and C2 operates relay E, which at E2 closes the testing circuit. Assume the order-wire is engaged: T will not operate: relay F operates through E1: relay G operates through F1: the testing circuit is now opened at G2. Relay E is now released by G1 and in turn releases F and G. Relay E again operates and the testing circuit is again closed. Relays E, F and G are slow releasing so that it will be seen that the testing circuit is closed only for the short part of the cycle taken for F and G to operate while it is held open for the long part of the cycle during which E, F and G release and E operates. Due to the inevitable difference in the timing of the E, F and G relays the periodicity of this cycle will be different for every A position, so that when the order-wire goes free it is extremely unlikely that the circuit of two testing relays will be closed at the same time and that first closed will, of course, obtain access to the order-wire. Further, even if two testing circuits are actually closed when the order-wire goes free, neither relay will operate on that cycle of the flicker circuit, but since on the next cycle the phase of the two flicker circuits will have altered, one of the testing relays will get in.

The only other circuit arrangement of interest is that of the junction assignment coding relays which is shown in Fig. **8.**

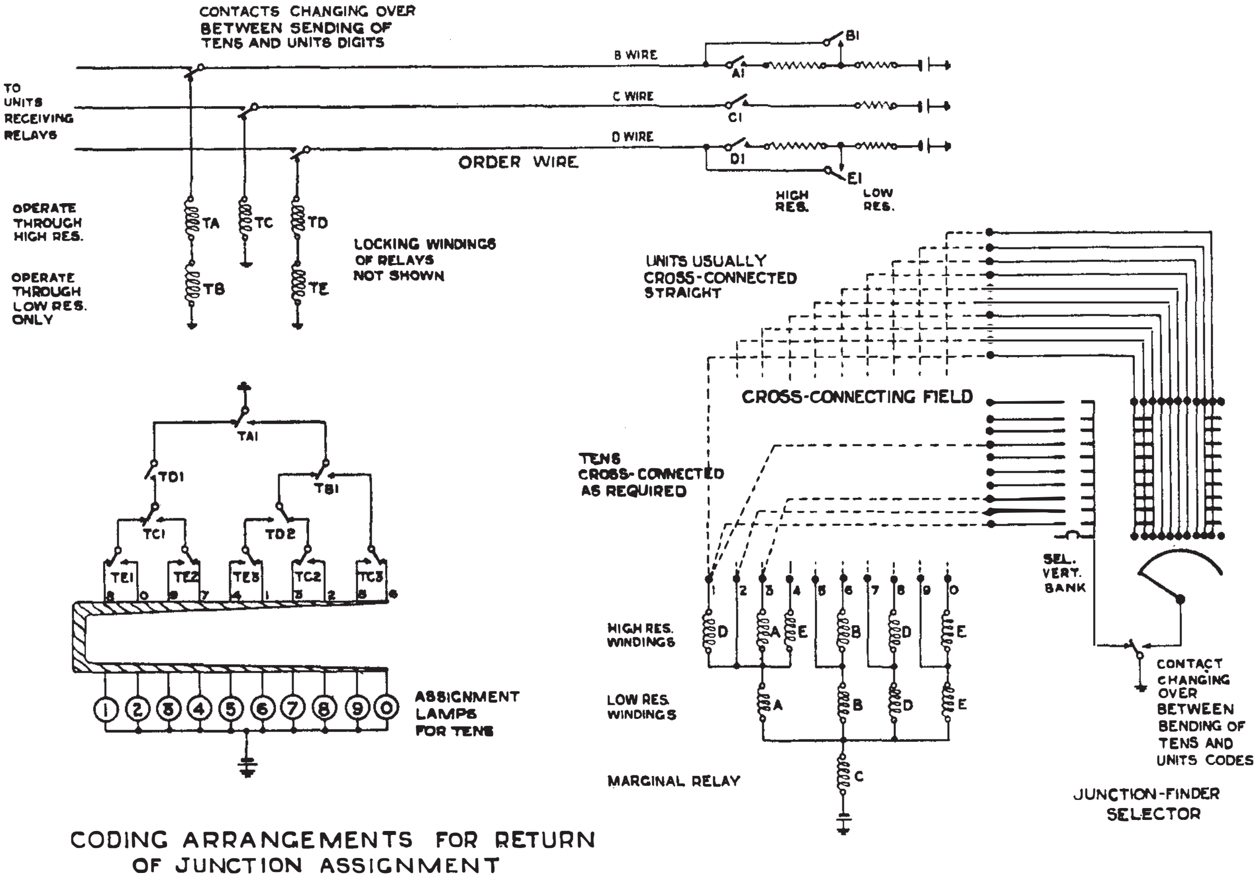

CONTACTS CHANGING OVER BETWEEN SENDING OF TENS AND UNITS DIGITS
TO UNITS RECEIVING RELAYS
B WIRE
C WIRE
D WIRE
ORDER WIRE
B1
A1
C1
D1
E1
HIGH RES.
LOW RES.
OPERATE THROUGH HIGH RES.
OPERATE THROUGH LOW RES. ONLY
TA
TC
TD
TB
TE
LOCKING WINDINGS OF RELAYS NOT SHOWN
UNITS USUALLY CROSS-CONNECTED STRAIGHT
CROSS-CONNECTING FIELD
TENS CROSS-CONNECTED AS REQUIRED
SEL. VERT. BANK
TA1
TD1
TB1
TC1
TD2
TE1
TE2
TE3
TC2
TC3
1 2 3 4 5 6 7 8 9 0
HIGH RES. WINDINGS
D A E B D E
LOW RES. WINDINGS
A B D E
MARGINAL RELAY
C
CONTACT CHANGING OVER BETWEEN SENDING OF TENS AND UNITS CODES
JUNCTION-FINDER SELECTOR
ASSIGNMENT LAMPS FOR TENS
1 2 3 4 5 6 7 8 9 0
CODING ARRANGEMENTS FOR RETURN OF JUNCTION ASSIGNMENT

Fig. **8.**

This circuit could be arranged in many ways; that shown is reasonably economical in relays while at the same time being straightforward and simple. The coding relays A, B, D and E have high and low resistance windings as shown, while C is a marginal relay which operates through the low resistance windings but does not operate when a high resistance winding is in circuit. An earth applied through either the vertical or rotary wipers to the first contact will therefore operate relays D and A but not C and by connecting battery through high resistances to the B and D wires of the order-wire, will operate relays TA and TD at the manual end and so light lamp No. 1 in the assignment indicator. The following table gives the coding and receiving relays operated and the conditions on the order-wire for the various digits:—

Digit.	Coding Relays Operated.	Condition on Order Wire. B Wire.	C Wire.	D Wire.	Receiving Relays Operated.
1	AD	HR–		HR–	TA TD
2	AC	HR–	LR–		TA TC
3	A	HR–			TA
4	AE	HR–		LR–	TA TD TE
5	BC	LR–	LR–		TA TB TC
6	B	LR–			TA TB
7	DC		LR–	HR–	TC TD
8	D			HR–	TD
9	EC		LR–	LR–	TC TD TE
0	E			LR–	TD TE

TRAFFIC CARRYING ABILITY OF THE SCHEME.

Since mechanical order-wire operation is in principle very similar to manual order-wire operation, it follows that the traffic considerations involved are also of a similar nature. There are, however, two important distinctions between manual and mechanical operation which should be appreciated.

In the first place, the order-wire gives access to a gang of mechanical-operators instead of to only one operator as in the manual case. Now since the natural manual condition of one operator to one order-wire is departed from, it follows that a sufficient number of mechanical-operators can be provided to ensure that the order-wire itself is fully loaded. This means that the load on the order-wire is limited only by its own capacity to transmit numbers and return assignments and not, as is the case in manual operation, by the " B " operators' capacity to set up connections.

In the second place, since the mechanical-operators do not suffer from fatigue, the order-wire can be kept loaded up to its full capacity for an indefinite period.

The load on the order-wire being thus freed from any restriction due to the capacity of the " B " operator the number of calls which the order-wire can carry may now be considered, and this capacity is now dependent purely on the time taken to handle each call and the average time which can be permitted in waiting for the order-wire to go free.

Observations show that the average time taken to make a call over the order-wire, that is to key up the four digits on the key-strip and to read the number of the junction assigned is 2.0 seconds or 0.5 seconds less than the corresponding time in manual practice: 2.25 seconds may be taken as a safe figure.

The waiting time is, of course, of great importance and should not be allowed to exceed that provided in manual practice. We may, therefore, take as the load for one order-wire the normal load for one order-wire under the best manual conditions. This load is taken to be 460 calls per hour and calculations based on Erlang's formulæ for waiting times show that this will give an average waiting time per call of 0.5 seconds for the mechanical order-wire compared with 0.6 seconds in the manual case.

So far no advantage has been taken of the removal of the restriction due to the manual " B " operator, but when a group of order-wires to the same exchange is considered, this feature of mechanical operation becomes really important. It is, of course, well known that the separate circuits of a group can be worked at much greater efficiency than a single circuit, so that the load on an order-wire forming one of a group can be much greater than that on a single order-wire while still maintaining the same average waiting time on the group. With the restriction due to the manual " B " operator removed this advantage can be fully utilised by merely ensuring that the number of mechanical-operators provided is sufficient to handle the increased load and the following figures give an indication of the advantage thus obtained :—

	MANUAL	MECHANICAL		
	One O.W.	One O.W.	Two O.Ws.	Three O.Ws.
Calls per hour per group	460	460	1520	2560
Calls per hour per O.W.	460	460	760	853
Average waiting time in secs.	0.6	0.5	0.3	0.2
Connections with no delay	68%	71%	74%	75%

It will be noticed that the loads per order-wire for groups of 2 and 3 order-wires are 760 and 853 calls per hour respectively. These are far in excess of anything accomplished in manual practice and yet the waiting times are less and the quality of service is therefore higher. As has been explained this is due to the removal of the limitation imposed by the physical capacity of the " B " operator.

The number of mechanical-operators required also depends on the average call duration and the waiting time permissible. The time taken for the mechanical operator to handle a call depends on the number of impulses in the trains constituting the required number, and from observation the average time from the depression of the order-wire key until the release of the mechanical-operator is found to be 8 seconds: 9 seconds may be taken as a safe figure and will allow for the few cases where delay occurs due to the " A " operator delaying in taking the junction. As previously explained, the waiting time on the mechanical-operators should be so short that it can never appreciably affect the service given by the order-wire. The provision of mechanical-operators on this basis is shown by the curves in Fig. **9**, which curves also show the necessary provision of order-wires and junctions for loads from zero up to 2,500 calls per hour.

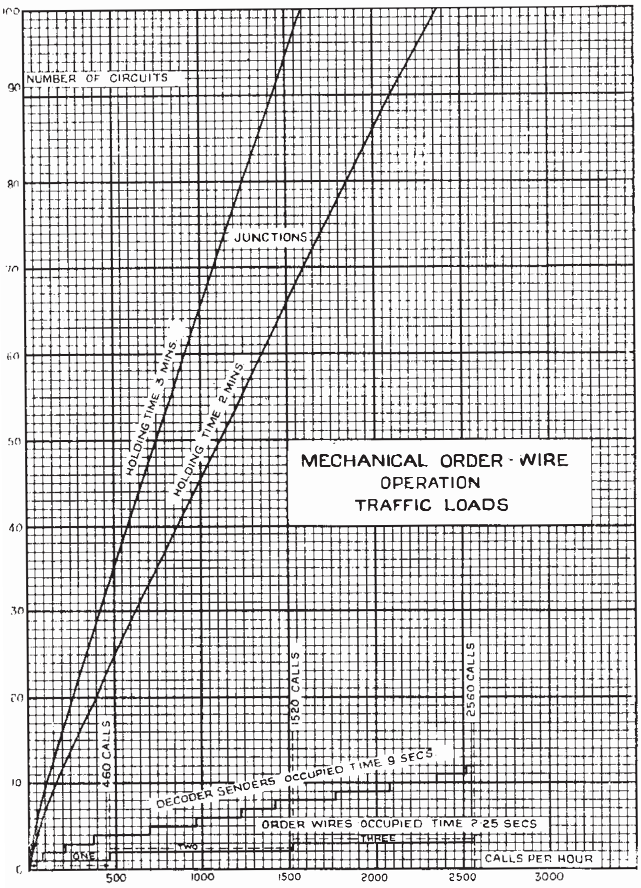


FIG. 9.

SIZE OF JUNCTION GROUPS.

The arrangements which have been described are particularly suitable for the operation of groups approaching a hundred junctions. Where a smaller junction group is concerned the type of switch used for the junction-finder may be varied and the preselector type employed if suitable. On the other hand, where a number of small groups of junctions from different manual exchanges converge on an automatic exchange it may be convenient to retain the selector type of junction-finder and connect the various junction groups to different levels of the finder multiple. In this case it is necessary to definitely associate certain mechanical-operators with each particular group, in order to avoid the mechanical-operators by chance segregating themselves on certain junction groups and leaving others unattended: the condition is easily catered for by arranging each of the finder switches to restrict its search to the level or levels corresponding with the junction group with which it is associated. This arrangement renders it easy to transfer an operator from one group to another as may be required by variations of traffic.

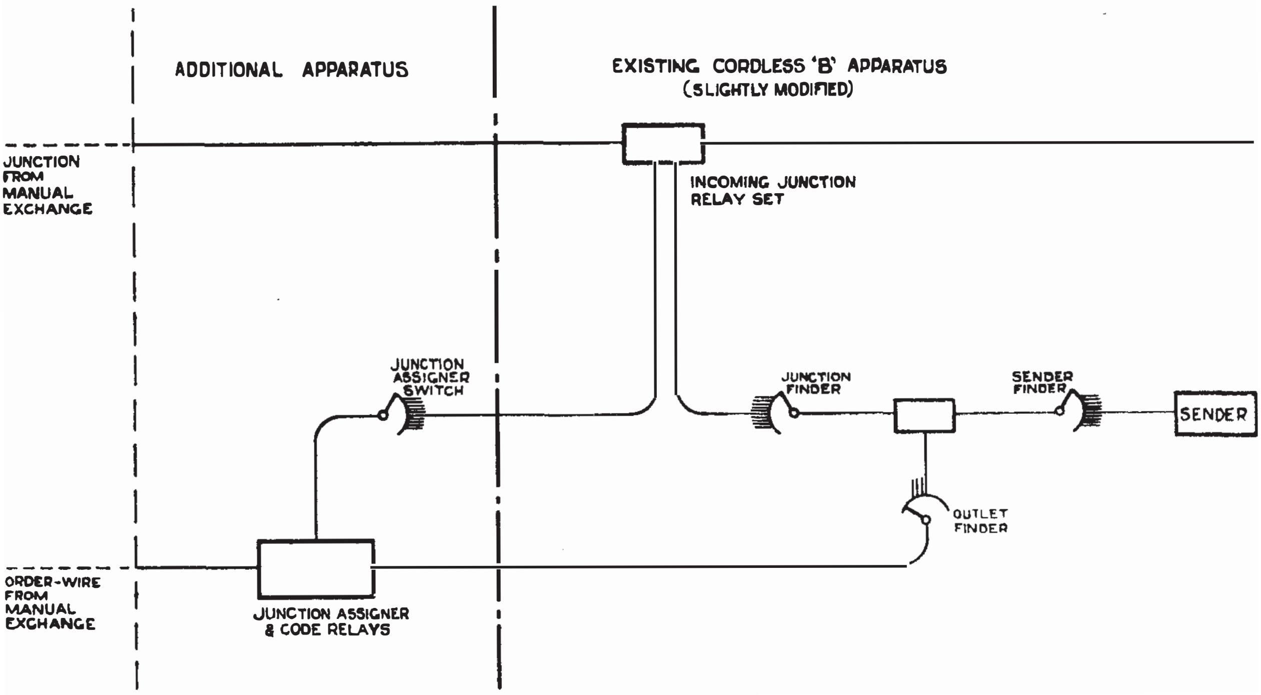
Another condition is where the junction group exceeds one hundred junctions. This condition may be met by operating the junctions as two entirely separate groups, each of not more than one hundred junctions and having separate order-wires for each group. The " A " operators would recognise which order-wire had been used and would take the assigned junction in the corresponding group. If desired, two extra lamps may be fitted on the junction-indicator to indicate the hundred and these can readily be controlled direct from the order-wire key depressed without in any way affecting the order-wire circuits themselves.

ADAPTION OF THE SCHEME TO AN AREA IN WHICH CORDLESS " B " WORKING IS ALREADY IN OPERATION.

The principle of mechanical order-wire operation is not restricted to the precise arrangements already described, and a case which justifies special consideration is that in which cordless " B " operation is already in use.

In this case the possibility of using the existing cordless " B " apparatus at the automatic exchange arises, and in the case of the Department's standard cordless " B " arrangements it is possible to make use of all the existing apparatus, except, of course, the cordless " B " sections themselves, with only the most trifling alterations to the wiring.

The general principle of this adaption is to provide a switch at the automatic end which will perform automatically the functions of assigning a free junction and of transmitting the number of the junction so assigned back to the junction-indicator at the manual exchange. A diagrammatic representation of these arrangements is shown in Fig. **10**, in which the existing apparatus is shown on the right hand and the extra apparatus required is shown on the left hand of the diagram.


ADDITIONAL APPARATUS
EXISTING CORDLESS 'B' APPARATUS (SLIGHTLY MODIFIED)
JUNCTION FROM MANUAL EXCHANGE
INCOMING JUNCTION RELAY SET
JUNCTION ASSIGNER SWITCH
JUNCTION FINDER
SENDER FINDER
SENDER
OUTLET FINDER
ORDER-WIRE FROM MANUAL EXCHANGE
JUNCTION ASSIGNER & CODE RELAYS

ADAPTION OF MECHANICAL ORDER-WIRE OPERATION TO MAKE USE OF EXISTING CORDLESS 'B' APPARATUS

Fig. **10**.

With this arrangement what has previously been termed the mechanical-operator has been split up into several distinct parts and the functions divided as follows:—The selection of the junction is performed by the " assigner switch "; the " outlet finder," " junction finder " and " sender finder " switches perform the previously unnecessary function of coupling the order-wire to a free sender and connecting that sender to the assigned junction; the codes keyed up by the " A " operator are received and retransmitted as impulses by the sender; and the assignment is reverted to the " A " position by the " assigner switch."

Consequent on the above differences a slightly greater time will elapse before the " A " operator can key up the number required, since search for a free sender has to be made before this may be done. Further, it will be noted that when more than one order-wire is required between two exchanges each order-wire has access only to a particular group of junctions instead of any junction being available to any order-wire.

Ecomomic Aspect.

Space does not permit of an exhaustive analysis of the economic aspect of mechanical order-wire operation and it would indeed be difficult to give complete data on this subject, chiefly because the additional apparatus required at the " A " positions is practically all common to the position and therefore becomes increasingly efficient as the number of order-wires operated on a mechanical basis increases.

A comparison with cordless "B" operation in the case of a typical instance will, however, be indicative of the economies to be expected. The instance selected is that of an area having six automatic and three manual exchanges with order-wires and junction groups as follows:—

	A1		A2		A3		A4		A5		A6	
	Jts.	O.Ws.	Jts.	O.Ws.	Jts.	O.Ws.	Jts.	O.Ws.	Jts.	O.Ws.	Jts.	O.Ws.
M1 (60 'A' posns)	30	1	10	1	20	1	25	1	12	1	30	1
M2 (40 ,,)	20	1	8	1	15	1	20	1	8	1	15	1
M3 (50 ,,)	30	1	10	1	15	1	20	1	20	1	20	1
Total	80	3	28	3	50	3	65	3	40	3	65	3

The relative number of mechanical-operators and cordless "B" positions for such a case would be approximately as under:—

	A1	A2	A3	A4	A5	A6
Mechanical-Operators ...	11	6	9	10	7	10
Cordless "B" Positions...	3	1	2	3	2	3

Comparative costs based on the above figures show that the total capital cost of the mechanical order-wire equipment is only about £3,800 more than the cost of the cordless "B" equipment, while both the operators' quarters and the services of at least twenty operators are rendered unnecessary at the automatic exchange.

EQUIVALENT T's FOR TELEPHONE TRANSFORMERS.

H. J. GREGORY, B.Sc., Whit.Ex., A.M.I.E.E.

IT is convenient when making calculations concerning the transmission efficiency of subscribers' instruments and cord circuits to consider the induction coil or repeating coil as represented by a network of impedances forming a T. The derivation of the equivalent T for a telephone transformer may be considered as follows:—

These transformers have an iron core, consequently the impedance of the windings will be affected by the hysteresis and eddy current losses in the core. The conditions obtaining in an iron-cored transformer may be represented by Fig. 1, in which the third winding with its circuit closed imitates the iron core losses.

x, y and z are the currents in the primary, secondary and tertiary windings respectively.

The equations for this network are:—

$$E = x(r_1 + j\omega l_1) + y(j\omega m_1) + z(j\omega m_3) \quad \text{.................(1)}$$

$$O = x(j\omega m_1) + y(r_2 + j\omega l_2) + z(j\omega m_2) \quad \text{.................(2)}$$

$$O = x(j\omega m_3) + y(j\omega m_2) + z(r_3 + j\omega l_3) \quad \text{.................(3)}$$

from which it follows that

$$y = -x \frac{j\omega m_1 + \dfrac{\omega^2 m_2 m_3 (r_3 - j\omega l_3)}{r_3^2 + \omega^2 l_3^2}}{r_2 + j\omega l_2 + \dfrac{\omega^2 m_2^2 (r_3 - j\omega l_3)}{r_3^2 + \omega^2 l_3^2}} \quad \text{.........(4)}$$

$$E = x \left[\left(r_1 + j\omega l_1 + \frac{\omega^2 m_3^2 (r_3 - j\omega l_3)}{r_3^2 + \omega^2 l_3^3} \right) - \frac{\left(j\omega m_1 + \dfrac{\omega^2 m_2 m_3 (r_3 - j\omega l_3)}{r_3^2 + \omega^2 l_3^2} \right)^2}{r_2 + j\omega l_2 + \dfrac{\omega^2 m_3^2 (r_3 - j\omega l_3)}{r_3^2 + \omega^2 l_3^2}} \right] \quad \text{......(5)}$$

If there had been no iron losses, the conditions would be represented by Fig. **1** with the tertiary winding removed and equations (4) and (5) would be reduced to

$$y = -x\,\frac{j\omega m_1}{r_2 + j\omega l_2} \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

$$E = x\left[\, r_1 + j\omega l_1 - \frac{(j\omega m_1)^2}{r_2 + j\omega l_2} \,\right] \quad\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Comparing equations (4) with (6) and (5) with (7) it will be seen that the effect of the losses in the iron core is apparently to make the effective resistance of the primary winding.

$$r_1 + \frac{\omega^2 m_3^2 r_3}{r_3^2 + \omega^2 l_3^2}$$

(r_1 is the D.C. resistance).

and its inductance is reduced to (8)

$$l_1 - \frac{\omega^2 m_3^2 l_3}{r_3^2 + \omega^2 l_3^2}$$

Similarly the effective resistance of the secondary circuit is increased to

$$r_2 + \frac{\omega^2 m_2^2 r_3}{r_3^2 + \omega^2 l_3^2}$$

and its inductance reduced to (9)

$$l_2 - \frac{\omega^2 m_2^2 l_3}{r_3^2 + \omega^2 l_3^2}$$

The mutual impedance beween the primary and secondary circuits, according to (4) and (5), has a resistance component

$$\frac{\omega^2 m_2 m_3 r_3}{r_3^2 + \omega^2 l_3^2}$$

and the mutual inductance is reduced to (10)

$$m_1 - \frac{\omega^2 m_2 m_3 l_3}{r_3^2 + \omega^2 l_3^2}$$

If the impedance of the primary winding is measured with the secondary winding on open circuit the result would be

$$r_1 + \frac{\omega^2 m_3^2 r_3}{r_3^2 + \omega^2 l_3^2} + j\omega\left(l_1 - \frac{\omega^2 m_3^2 l_3}{r_3^2 + \omega^2 l_3^2}\right)\ldots(11)$$

The same applies to the impedance of the secondary winding and the mutual impedance.

Suppose we have two coils AC and BC of inductance L_1 and L_2 respectively, with a mutual inductance M between them as shown in Fig. **2.** If these two coils are joined together at C so that the coils in series are assisting, then this arrangement can be represented by the equivalent T shown in Fig. **3.*** This will be evident if the inductance between corresponding letters on the two diagrams are considered. If the coils are joined in series opposing as in Fig. **4,** the equivalent T will be as shown in Fig. **5.** Similarly if the two coils are separate as in Fig. **6,** they can be represented mathematically by the equivalent T of Fig. **7** or Fig. **8.** This also applies if the impedances have resistance components.

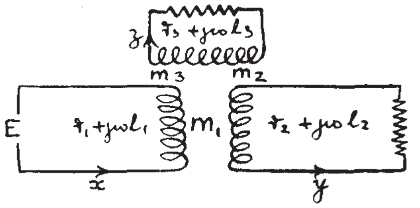


FIG. 1

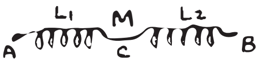


FIG. 2.

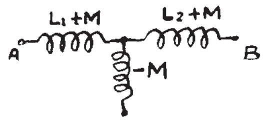


FIG. 3

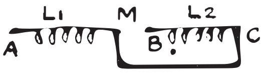


FIG. 4.

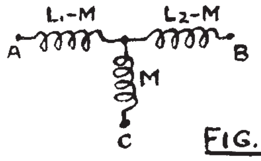


FIG. 5

SUBSCRIBERS' INSTRUMENT CIRCUITS.

The transmitter may be considered to be a generator of alternating current and if its variation of resistance is $r_0 \sin \omega t$ and the feeding current is I then its E.M.F. will be $E = Ir_0 \sin \omega t$, neglecting harmonics. Also if the D.C. resistance of the transmitter is r and is taken to be the internal impedance of the generator, the conditions for a L.B. instrument may be represented by Fig. **9**, and its equivalent Fig. **10**.

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* *See Bibliography 1.*

Similarly the C.B. instrument shown in Fig. **11** may be represented by Fig. **12** for Sending and Fig. **13** for Receiving. The induction coil is connected as an autotransformer.

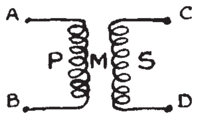


FIG. 6

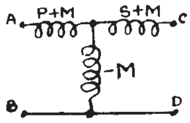


FIG. 7

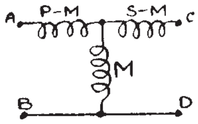


FIG. 8.

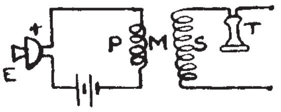


FIG. 9.

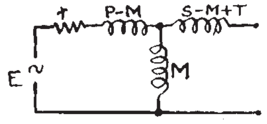


FIG. 10

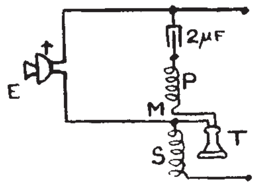


FIG. 11.

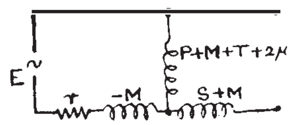


FIG. 12.

The information required for the construction of the equivalent T's can be obtained from the results of impedance tests. In making these tests it is necessary to keep the flux in the core in approximately the same condition as regards A.C. and D.C. as obtains in practice. In the case of L.B. induction coils the following tests are made:—

1. Impedance with 0.3 volt A.C. of the primary winding with 30 mA D.C. fed to the secondary winding through high impedance retards.
2. Test repeated with 200 ohm non-inductive resistance in place of the retards.
3. Impedance with 1 volt A.C. of the secondary winding with 100 mA D.C. fed to the primary winding through high impedance retards.
4. Test 3 repeated with 20 ohm non-inductive resistance in place of the retards.

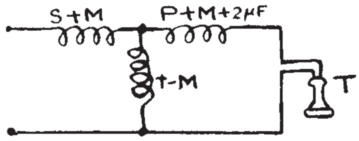


FIG. 13.

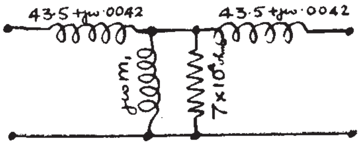


FIG. 16.

Equivalent T for Repeating Coil 4003A

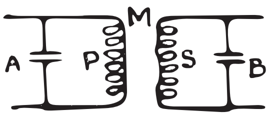


FIG 18

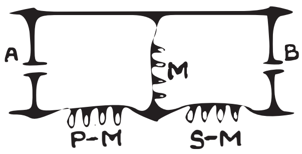


FIG. 19.

The values of A.C. and D.C. are intended to give approximately the same ampere turns for all the tests. In tests 1 and 3 the impedance of the retards is so high compared with that of the induction coil windings that the coil may be considered to be on open circuit as regards A.C. If Z_p is the impedance of the winding as measured by Test 2 and R is the non-inductive resistance across the other winding, then from a consideration of the equivalent T in Fig. **8** it will be readily seen that

$$Z_p = P - M + \frac{M\,(S - M + R)}{M + S - M + R}$$

$$\therefore \quad M = \sqrt{(P - Z_p)\,(S + R)} \quad \ldots\ldots\ldots\ldots\ldots\ldots(12)$$

Similarly if Z_s is the result obtained by Test 4

$$M = \sqrt{(S - Z_s)\,(P + R)}$$

The value of M can therefore be calculated twice from the results of the four tests. These two calculated values should be equal.

The impedances of an average L.B. induction coil $1^{\omega}/25^{\omega}$ are at 5,000 radians per second.

$$\begin{aligned} P &= 2.0 + j\,27.8 \\ S &= 36.2 + j271.5 \\ M &= 3.8 + j\,79.5 \end{aligned}$$

The tests on C.B. induction coils are made with 1 volt A.C. across each winding and with 50 mA D.C. The impedances of an average coil at 5,000 radians per second are

$P = 48 + j381$ (26 ohm winding)

$S = 45 + j534$ (17 ohm winding)

$M = 25 + j439$

The impedances of induction coils are affected very little by direct current.

4003A REPEATING COILS.

These coils are 1 : 1 ratio transformers, and as they are toroidal coils wound on a core of iron wire they have very little magnetic leakage. The inductance of the windings, however, is considerably affected by direct current. In order to obtain the equivalent T for a repeating coil at speech frequencies and with the values of direct current obtaining in practice some were tested in the following manner :—

Test 1. Impedance with a P.D. of 1 volt at the stated frequency, of winding 2—1—6—5 with six 5L retards in series connected across the winding 4—3—8—7 and with a battery of the necessary voltage to give the value of direct current desired in the latter winding.

Test 2. Impedance with a P.D. of 1 volt at the stated frequency of winding 2—1—6—5 with 300 ohms connected across the winding 4—3—8—7 and with a battery in series with this resistance to give the same value of direct current as in Test 1.

Test 3. Same as Test 1, but with windings 4—3—8—7 and 2—1—6—5 interchanged.

Test 4. Same as Test 2, but with windings interchanged.

In order to obtain the results given below these four tests were repeated for several frequencies and with several values of direct current at each frequency. In Tests 1 and 3 the impedance obtained will be lower than the real value for the winding as this impedance is not negligible compared with that of the six retards in series. The impedance of these retards, however, was known under the various conditions of the tests and their effect on the observed values of the impedances of the repeating coil windings were allowed for in the following manner.

From a consideration of the equivalent T, given in Fig. **8**, it follows that if Z is the impedance of the six retards in series and P_1 is the observed impedance of the primary winding,

$$\text{then } P_1 = P - M + \frac{M(S - M + Z)}{S - M + Z + M}$$

$$= P - \frac{M^2}{S + Z}$$

$$\therefore\ P = P_1 + \frac{M^2}{S + Z}$$

But $\frac{M^2}{S + Z}$ is the correcting factor which, in this case, is small compared with P and the error in P will be quite small if $\frac{M^2}{S + Z}$ be assumed to be equal to $\frac{P_1^2}{P_1 + Z}$

We then have the real value for the impedance of the winding

$$P = P_1\left(1 - \frac{P_1}{P_1 + Z}\right) \quad \text{..........................(13)}$$

The following Table 1 contains the mean results of impedance tests made on a number of repeating coils 4003A, made with a P.D. of 1 volt at several frequencies and with different values of direct current flowing through one half of the coil. The impedances of the two windings were found to be equal and the mutual impedance has been calculated in the same manner as described for induction coils.

TABLE I.

IMPEDANCE OF REPEATING COILS 4003 A.

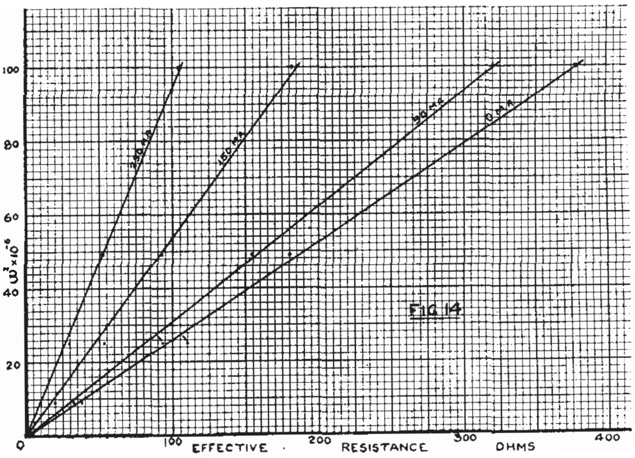
Frequency Radians per sec.	Direct Current M.A.							
	O		50		150		250	
	R	L	R	L	R	L	R	L
Half Coil.	ohms	Henry	ohms	Henry	ohms	Henry	ohms	Henry
3000	81.5	·536	77	·4873	64.2	·3746	55·2	.2776
5000	154	·550	138	·5048	98	·3740	75	.2784
7000	223	·534	197·5	·4919	136.6	·3797	96	.2822
10000	421	·5385	360	·4932	224	·3758	147	.2838
Mean		·5396		·4944		·3750		.2805
Mutual.								
3000	38	·5313	32·3	·4833	19·4	·3704	9.8	·2733
5000	110	·5460	94	·5012	53	·3700	30	.2746
7000	180	·5294	154	·4871	93.6	·3759	52.6	.2786
10000	379	·5340	320	·4890	182	·3718	104.5	·2793
Mean		·5352		·4901		·3720		.2767
Difference between the impedance of Half-Coil and the Mutual Impedance.								
3000	43·5		44·7		44.8		45·4	
5000	44		44		45		45	
7000	43		43·5		43		43·4	
10000	42		40		42		42·5	
Mean	43·1	.0044	43·0	.0043	43·7	.0040	44·1	.0038

Average difference $= 43{\cdot}5$ ohms $+ j\omega.0042 = P - M = S - M$.

Average D.C. resistance of Windings 41.5 ohms.

The following points may be noted from these results :—

1. The inductances of the windings (P and S) and the Mutual inductance are affected very little by the frequency of the testing current. A very slight increase with frequency was obtained, which is practically negligible.
2. The difference between the inductance of the windings and the mutual inductance is due to magnetic leakage and decreases slightly as the inductances decrease, but may be taken as .0042 henry on the average.
3. The difference between the effective resistance of the windings and the resistance component of the mutual impedance is the same for all frequencies and values of direct current, allowing for experimental error. This difference on the average is 43.5 ohms and is near to the average D.C. resistance of the windings, 41.5 ohms.
4. Plotting the effective resistance of the mutual impedance against the frequency squared in Fig. **14** shows that proportionality holds between these quantities.



5. Plotting the resistance component of the mutual impedance against the mutual inductance squared in Fig. **15** shows that proportionality holds also between these quantities.

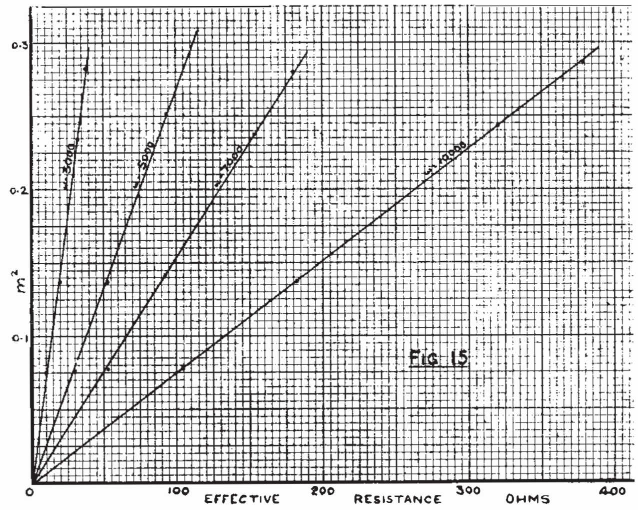


FIG 15

6. Dividing these same resistance figures by the corresponding values of $\omega^2 m_1^2$ gives the following results :—

TABLE 2.

Frequency Radians per sec.	Direct Current M.A.			
	0	50	150	250
3000	$.149 \times 10^{-4}$	$.153 \times 10^{-4}$	$.157 \times 10^{-4}$	$.146 \times 10^{-4}$
5000	$.147 \times 10^{-4}$	$.150 \times 10^{-4}$	$.154 \times 10^{-4}$	$.159 \times 10^{-4}$
7000	$.131 \times 10^{-4}$	$.133 \times 10^{-4}$	$.135 \times 10^{-4}$	$.138 \times 10^{-4}$
10000	$.133 \times 10^{-4}$	$.134 \times 10^{-4}$	$.132 \times 10^{-4}$	$.134 \times 10^{-4}$
Mean	$.140 \times 10^{-4}$	$.1425 \times 10^{-4}$	$.1445 \times 10^{-4}$	$.144 \times 10^{-4}$

Average = $.143 \times 10^{-4}$.

It may be of interest to see how the theory given at the beginning is borne out by the results obtained from these repeating coils.

As these coils are 1 : 1 ratio transformers and have very little magnetic leakage, we may write when neglecting magnetic leakage

$$l_1 = l_2 = m_1$$

$$\text{also } m_3 = \sqrt{l_1 l_3} = \sqrt{l_2 l_3} = m_2$$

The impedance of each winding from (11) is therefore

$$r_1 + \frac{\omega^2 l_1 l_3 r_3}{r_3^2 + \omega^2 l_3^2} + j\omega\left(l_1 - \frac{\omega^2 l_1 l_3^2}{r_3^2 + \omega^2 l_3^2}\right) \ldots (14)$$

and the mutual impedance from (10) is

$$\frac{\omega^2 l_1 l_3 r_3}{r_3^2 + \omega^2 l_3^2} + j\omega\left(m_1 - \frac{\omega^2 l_1 l_3^2}{r_3^2 + \omega^2 l_3^2}\right) \ldots (15)$$

So that the difference between the effective resistance of the winding and the resistance component of the mutual impedance is r_1 the D.C. resistance of the winding. (See 3 above).

The eddy currents produced in the iron core will be proportional to the rate of change of flux and consequently proportional to the frequency as well as the magnitude of the flux variations. In the case under consideration, the reduction in the inductance of the windings as the direct current increases is due to the reduction in the permeability of the core and this inductance will be proportional to the permeability. The eddy currents are therefore proportional to the frequency and the inductance of the windings. The watts lost due to eddy currents will therefore be proportional to the square of both the frequency and inductance. Figs. **14** and **15** therefore indicate that the core losses are due to eddy currents. This appears reasonable since the variation of flux due to the alternating current is very small and would not be expected to cause appreciable hysteresis loss.

Reverting to equation (15) given above, it follows that the mutual impedance is

$$\frac{\omega^2 m_1 r_3 l_3}{r_3^2 + \omega^2 l_3^2} + j\omega m_1\left(1 - \frac{\omega^2 l_3^2}{r_3^2 + \omega^2 l_3^2}\right)$$

$$= \omega m_1 r_3 \times \frac{\omega l_3 + j r_3}{r_3^2 + \omega^2 l_3^2}$$

$$= \frac{m_1}{l_3}\left(\frac{1}{\dfrac{1}{r_3} + \dfrac{1}{j\omega l_3}}\right)$$

This latter expression means that the mutual impedance is equal to the two impedances $j\omega m_1$ and $\frac{r_3 m_1}{l_3}$ in parallel.

It therefore appears that the tertiary winding containing $r_3 + j\omega l_3$ of Fig. **1** represents the paths of the eddy currents and that these losses are represented by a resistance $\frac{r_3 m_1}{l_3} = G$ in parallel with the mutual inductance. Further, as m_1 and l_3 are both proportional to the permeability of the core, the resistance G will be a constant quantity for all frequencies and conditions of magnetisation of the core and is determined only by the specific resistance of the core material and the dimensions of the magnetic circuit.

This resistance G is shown by Steinmetz (see Chap. XIV., Alternating Current Phenomena) to be equal to $\frac{\cdot 507\,\epsilon\lambda l}{An^2}$

where l = length of the magnetic circuit
A = cross section of the magnetic circuit
n = number of turns in the windings
λ = electric conductivity of the iron core.
ϵ is the coefficient of eddy currents
and for an iron wire core
$\epsilon = 0.617\, d^2 \times 10^{-9}$
where d = diam of the iron wire;
and for laminated cores
$\epsilon = 1.645 a^2 \times 10^{-9}$
where a = thickness of the stampings.

The figures for the mutual impedance in Table 1 are in the form $R + jX$ and the value of m_1 and G may be obtained as follows. The mutual admittance will be equal to the sum of the admittances $\frac{1}{j\omega m_1}$ and $\frac{1}{G}$

$$\frac{1}{R+jX} = \frac{1}{j\omega m_1} + \frac{1}{G}$$

$$\therefore \frac{R-jX}{R^2+X^2} = -\frac{j}{\omega m_1} + \frac{1}{G}$$

$$\therefore G = \frac{R^2+X^2}{R} \text{ and } \omega m_1 = \frac{R^2+X^2}{X} \ldots\ldots (16)$$

From the results given in Table 1 it is evident that for practical purposes R^2 is sufficiently small compared with X^2 to write

$$G = \frac{X^2}{R} \text{ and } \omega m_1 = X$$

This means that the inductance figures given for m_1 stand unaltered and that G is the reciprocal of the figures given in Table 2.

The mean value for G is therefore 7.0×10^4 ohms. The very slight increase of the mutual inductance with frequency as indicated in Table 1, is probably due to a very small self-capacity in the windings. The reduction of the figures in Table 2 with frequency may be due to hysteresis losses. Both of these effects are negligible for practical purposes and a repeating coils 4003A may be represented by the equivalent T of Fig. **16** under any condition of frequency, and direct current in the windings where the mutual inductance m_1 for the required value of direct current is given in Fig. **17**.

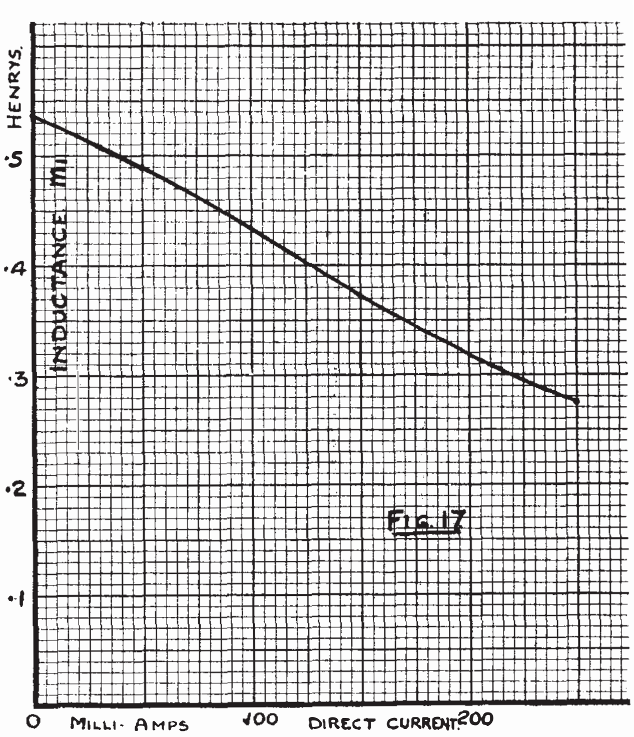


FIG. 17

REPEATING COILS 4006A.

In repeating coils 4003A the self-capacity of the windings is so small that it can be neglected. Repeating coils 4006A, however, are differentially wound, consequently there is appreciable capacity between windings 2—1 and 6—5 and also between 4—3 and 8—7. If it be assumed that the self-capacity of a winding of a transformer may be represented by an equivalent capacity shunted across the terminals of the winding, the conditions are represented by Fig. **18**. A and B are the impedances of these equivalent capacities. P, S and M would be the primary, secondary and mutual impedances respectively, if the transformer windings had no self-capacity. Applying the principle of the equivalent T the network of Fig. **19** will represent the transformer.

The π network of impedances consisting of A, P − M and M may be replaced by an equivalent T consisting of X, Y and Z as shown in Fig. **20.**

$$\text{where } X = \frac{AM}{A+P}\,;\ Y = \frac{A(P-M)}{A+P}\,;\quad Z = \frac{M(P-M)}{A+P}$$

Similarly the π network consisting of X, Z + S − M and B may be replaced by an equivalent T consisting of X^1, Y^1 and Z^1 as shown in Fig. **21.**

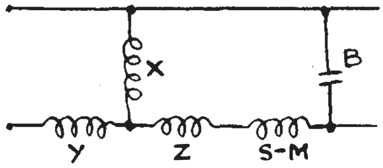


FIG. 20

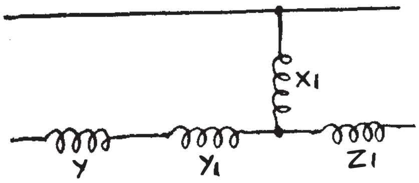


FIG. 21.

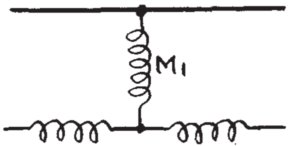


FIG 22.

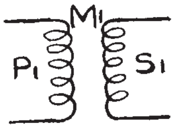


FIG. 23.

$$\text{where } X^1 = \frac{ABM}{D} : Y + Y^1 = \frac{AB}{D}(P-M) + \frac{A}{D}(PS-M^2)$$

$$Z^1 = \frac{AB}{D}(S-M) + \frac{B}{D}(PS-M^2)$$

$$\text{where } D = (A+D)(B+S) - M^2 \quad \text{...........}(17)$$

The transformer can therefore still be represented by an equivalent T as shown in Fig. **22.**

$$\left.\begin{aligned} \text{where } M_1 &= \frac{ABM}{D} : P_1 = \frac{ABP}{D} \\ &\quad + \frac{A}{D}(PS-M^2) \\ S^1 &= \frac{ABS}{D} + \frac{B}{D}(PS-M^2) \end{aligned}\right\} \quad \text{.........}(18)$$

The impedances of the windings as measured in the usual manner will be P^1 and S^1. The self-capacity of the windings of a transformer therefore does not introduce any difficulty in obtaining the equivalent T. If the impedances of the windings are measured in the usual manner and the equivalent T derived from the results as previously described, the self-capacity of the windings will be automatically accounted for.

Table 3 contains the results obtained from some 4006A repeating coils and some transformers Nos. 15A and 16A with a P.D. of 1 volt at several frequencies.

The measurements made were :—

1. Impedance of winding 2—1—6—5 with winding 4—3—8—7 on open circuit. This is P.
2. Impedance of winding 2—1—6—5 with 500 ohms non-inductive resistance across 4—3—8—7.
3. Impedance of winding 4—3—8—7 with winding 2—1—6—5 on open circuit. This is S.
4. Impedance of winding 4—3—8—7 with 500 ohms across 2—1—6—5.

The above are 1 : 1 ratio transformers and if the mutual impedance is obtained from these impedance test results by means of formula (12) and P − M and S − M obtained by subtraction, it will be evident that as this is a difference between two large quantities, inaccuracy is likely to occur. It was found preferable, therefore, to obtain P − M directly from the impedance measurements from the formula

$$P_1 - M = \frac{Z(P_1+R)}{2P_1} - \frac{R}{2} \quad \text{..........}(19)$$

which is an approximation derived from a consideration of the equivalent T and (12). The results for $P_1 - M$ and M, given in Table 3, were calculated from the mean of the impedance tests obtained on the two windings, *i.e.*, P_1 is the mean of tests 1 and 3 and Z is the mean of tests 2 and 4. R = 500 ohms. $P_1 - M$ therefore is the mean of P − M and S − M. The average value of P − M and S − M for all frequencies given in Table 3 have been arranged so that their mean is equal to $P_1 - M$ and the difference between their resistance components is the same as the difference between the D.C. resistances of the windings.

On comparing these results for P − M and S − M thus obtained with those for 4003A repeating coils it will be noticed that they are very similar. This leads one to suggest that a 4006A repeating coil may be represented by a network similar to that of Fig. **16** for 4003A coils, but with capacities added to represent the self-capacity of the windings as in Fig. **24.**

It will be seen later that the impedance of the self-capacities C_A and C_B at speech frequencies will be large compared with that of P − M and S − M, so that the network may be modified to Fig. **25** where $C = C_A + C_B$.

TABLE 3.

EQUIVALENT T's. FOR REPEATING COILS 4006A AND TRANSFORMERS Nos. 15A AND 16A.

Frequency Radians per second	P^1-M			M		
	R	X	L	R	X	
Repeating Coils a 4006A.						
3000	69.1	15.1	.00503	800	5625	
5000	69.5	24.2	.00484	3200	11520	For all frequencies.
7000	70.7	32.4	.00463	16700	19800	P − M = 74.6 + jω.0048
7500				24620	22960	S − M = 66.0 + jω.0048
8000				33800	22670	
8500				42310	6586	D.C. Resistance of P = 60.9 ohms
9000				34220	−11040	D.C. Resistance of S = 69.5 ohms
10000	71.8	46.5	.00465	19750	−18715	
Mean	70.3		.0048			
Transformers 15A.						
3000	67.0	14.5	.00482	769	8570	
5000	67.5	23.5	.00469	2385	18020	For all frequencies.
7000	68.2	32.4	.00463	13844	44910	P − M = 74.0 + jω.00467
7500				27460	60380	S − M = 62.0 + jω.00467
8000				72800	79700	
8500				148630	5850	D.C. Resistance of P = 70.6 ohms
9000				93830	−67250	D.C. Resistance of S = 58.5 ohms
10000	69.2	45.5	.00455	19800	−50400	
Mean	68.0		.00467			
Transformers 16A.						
3000	44.8	16.56	.00552	454	8160	For all frequencies.
5000	45.0	27.0	.0054	1257	15650	P − M = 43.2 + jω.0054
7000	45.0	37.64	.00538	4355	30220	S − M = 47.2 + jω.0054
8000				10615	47730	
9000				37800	83250	D.C. Resistance of P = 42.7 ohms
10000	45.8	53.6	.00536	144200	102200	D.C. Resistance of S = 46.7 ohms
Mean	45.2		.0054			

This is the equivalent T in which the mutual impedance consists of an inductance, resistance and capacity in parallel and is confirmed by the results given in Table 3, where for 4006A repeating coils M shows a resonance between 8,500 and 9,000 radians per second. It may be of interest now to consider a method of obtaining these three components of M. (See Bibliography No. 4).

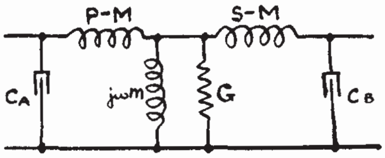


FIG. 24

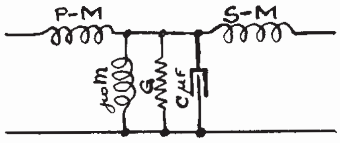


FIG. 25

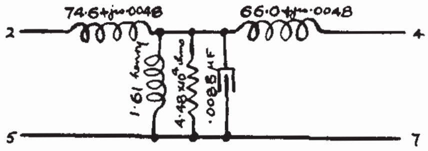


FIG 27. Equivalent T for 4006A Repeating Coil.

The results for M are given in the form $R+jX$ and, from Fig. **25**, its admittance is :—

$$\frac{1}{M}=\frac{1}{R+jX}=\frac{1}{j\omega m}+\frac{1}{G}+j\omega C$$

$$\therefore \frac{R-jX}{R^2+X^2}=-\frac{j}{\omega m}+\frac{1}{G}+j\omega C$$

$$\therefore \frac{R}{R^2+X^2}=\frac{1}{G} \quad \dots\dots\dots\dots\dots\dots\dots\dots(20)$$

$$\text{and } \frac{X}{R^2+X^2}=\frac{1}{\omega m}-\omega C$$

$$\therefore \frac{\omega X}{R^2+X^2}=-\omega^2 C+\frac{1}{m} \quad \dots\dots\dots\dots(21)$$

G may therefore be calculated from $\frac{R^2+X^2}{R}$ and if $\frac{\omega X}{R^2+X^2}$ is plotted against ω^2 a straight line should be obtained and from the intercept of ω^2, *i.e.*, when $\omega^2=O$, $\frac{\omega X}{R^2+X^2}=\frac{1}{L}$

Further, the slope of this line will be equal to C. From the results from 4006A coils, given in Table 3, the calculated figures in Table 4 have been derived.

TABLE 4.

ω	ω^2	R^2+X^2	$\frac{R^2+X^2}{R}=G$	$\frac{\omega X}{R^2+X^2}$
3000	9×10^6	32.3×10^6	40.4×10^3	.522
5000	25 ,,	143.2 ,,	44.8 ,,	.4025
7000	49 ,,	672 ,,	39.6 ,,	.206
7500	56.25	1137 ,,	46.2 ,,	.151
8000	64 ,,	1654 ,,	49.0 ,,	.110
8500	72.3 ,,	1833 ,,	43.4 ,,	.0305
9000	81 ,,	1292 ,,	37.8 ,,	−.077
10000	100 ,,	740 ,,	37.5 ,,	−.253

Mean for $G = 4.48 \times 10^4$.

ω^2 is plotted against $\frac{\omega X}{R^2+X^2}$ in Fig. **26** and the points lie fairly well along a straight line. The deduced results from Fig. **26** are $m=1.61$ henry and $C=.0085\ \mu F$.

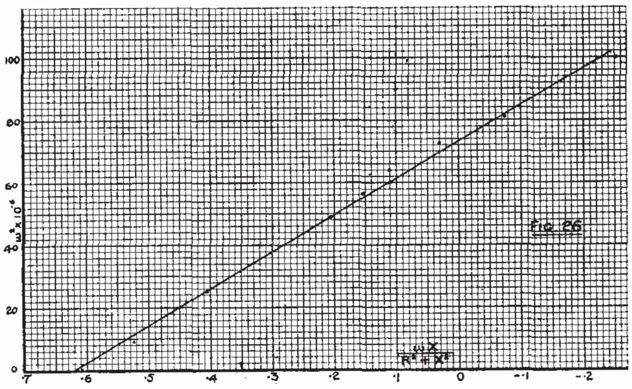


FIG. 26

A 4006A repeating coil can therefore be represented at any frequency between 3,000 and 10,000 radians per second by Fig. **27**.

Treating the results obtained from the Transformers 15A and 16A in the same way the values for G, *m*, and C were :—

For Transformer 15A.

$G = 14.4 \times 10^4$ ohms. $m = 2.5$ henrys.

$C = .00554\ \mu F$.

For Transformer 16A.

$G = 20.2 \times 10^4$ ohms. $m = 2.5$ henrys.

$C = 00374\ \mu F$.

The equivalent T's are consequently as shown in Figs. **28** and **29**.

TRANSFORMERS 15B, 15C, 16B and 16C.

These transformers are similar to repeating coils 4006A in that their windings have appreciable self-capacity, but their ratio of transformation is 1 : 1.263 for 15B and 16B and 1 : 1.61 for 15C and 16C. They can, however, be represented by Fig. **18** and the effect of the self-capacity on the impedance of the windings is shown in (18). The magnetic leakage of these coils is small, and if it be neglected we can write $PS - M^2 = O$. It then follows from (18) that the effect of self-capacity is to multiply all the three impedances P, S and M by the same factor $\frac{AB}{D}$

If the permeability of the core remains the same r_3 and l_3 in (14) will be constant with respect to frequency. The effective resistance and the reactance of each winding are therefore from (14) proportional to the inductance of the respective winding. Neglecting the D.C. resistance and magnetic leakage of the windings, it follows that the impedances of the windings should have the same angle and their ratio $\frac{\text{Secondary}}{\text{Primary}}$ should be equal to N^2 where N is the ratio of transformation, seeing that the inductance of a coil winding is proportional to the square of the number of turns it contains. Evidently, therefore, the impedance of the windings P and S of these transformers now being considered will have equal angles and their ratio will still be N^2 at any frequency notwithstanding their self-capacity. It is consequently convenient in the case of these transformers to consider their equivalent unity ratio transformer.* If the ratio of the secondary winding impedance to the primary is N^2 then the equivalent T for the unity ratio transformer will consist of $P - \frac{M}{N}$ $\frac{S}{N^2} - \frac{M}{N}$ and $\frac{M}{N}$ as shown in Fig. **30** and the impedance connected to the secondary winding must be divided by N^2.

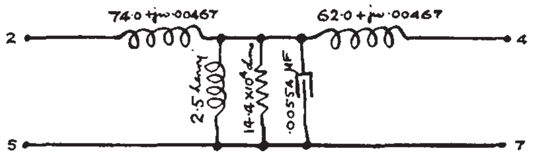


Fig 28. Equivalent T for Transformer 15A.

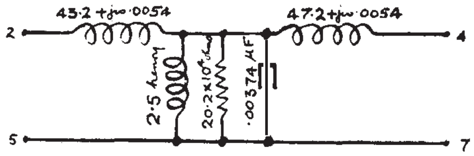


Fig. 29. Equivalent T for Transformer 16A.

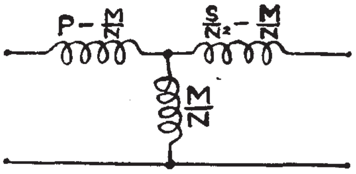


FIG. 30.

This equipalent ratio will be correct only if the D.C. resistance of the windings is small compared with their impedance and the magnetic leakage is small.

In obtaining the equivalent T for these transformers the same four tests were made as for 4006A repeating coils. These measurements are :—

P = impedance of winding 2—1—6—5

S = ,, ,, ,, 4—3—8—7

Z_1 = ,, ,, ,, 2—1—6—5 with 500 ohms across 4—3—8—7.

Z_2 = impedance of winding 4—3—8—7 with 500 ohms across 2—1—6—5.

The mean of the results obtained on some transformers 16B are given in Table 5, with the ratio N^2 calculated from the effective resistance and reactance figures. The values obtained from the reactance figures are probably the more nearly correct as the effective resistance is usually much the smaller figure, excepting at frequencies near the resonance point.

---

* *See Bibligraphy No. 2.*

For the same reason that $P-M$ was obtained direct from the impedance test results in the case of 4006A coils, it is desirable to obtain $P-\frac{M}{N}$ and $\frac{S}{N^2}-\frac{M}{N}$ in a similar manner, and the corresponding formulæ are:—

$$\left.\begin{aligned} P-\frac{M}{N} &= \frac{Z_1\,(S+R)}{2S}-\frac{R}{2N^2} \\ \frac{S}{N^2}-\frac{M}{N} &= \frac{Z_2\,(P+R)}{2PN^2}-\frac{R}{2} \end{aligned}\right\}\ldots\ldots\ldots(22)$$

where $R=500$ ohms in this case.

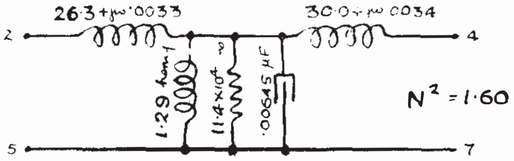
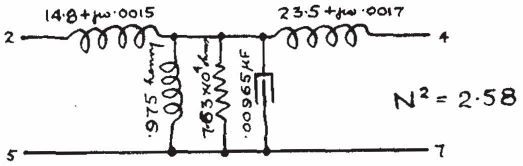


Fig 31.

Equivalent unity ratio T for Transformer 16B.



Equivalent unity ratio T for Transformer 16C

The values of $P-\frac{M}{N}$ and $\frac{S}{N^2}-\frac{M}{N}$ thus obtained from the impedance test results together with the corresponding values of $\frac{M}{N}$ are shown in Table 6.

TABLE 5.

IMPEDANCE TESTS OF TRANSFORMERS 16B.

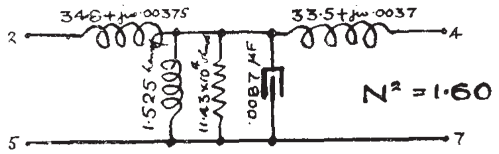
ω	P		S		N^2	
	R	X	R	X	From R	Form X
3000	327	4550	485	7155	1.49	1.57
5000	733	8045	1120	13100	1.535	1.63
7000	2120	15100	3250	23800	1.54	1.58
8000	3950	20900	6150	33300	1.56	1.59
9000	9300	32000	14830	51400	1.595	1.60
10000	40200	53900	63000	87400	1.57	1.62
					Mean	1.60

TABLE 6.

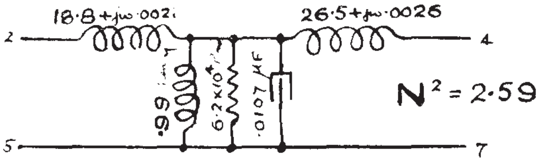
ω	$P-\frac{M}{N}$	$\frac{S}{N^2}-\frac{M}{N}$	$\frac{M}{N}$	
			R	X
3000	26.2+jω.0033	29.5+jω.0037	300	4540
5000	26.2+jω.0033	29.5+jω.0034	705	8030
7000	26.2+jω.0033	29.5+jω.00325	2094	15080
10000	26.5+jω.0033	31.0+jω.00322	40200	53870
Mean	26.3+jω.0033	30.0+jω.0034		

After obtaining $\frac{M}{N}$ by subtracting the results for $P-\frac{M}{N}$ from those for P and applying the method described for 4006A repeating coils, the three components making up $\frac{M}{N}$ have been calculated. The results are $L=1.29$ henry, $C=.00645$ μF and $G=11.4\times10^4$ ohms. The equivalent unity ratio T for transformers 16B and 16C is therefore shown n Fig. **31**.

Treating the results obtained from the other types of transformer in the same way the following equivalent T's have been obtained :—



Equivalent unity ratio T for Transformer 15B.



Equivalent unity ratio T for Transformer 15C.

FIG. 32.

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THE NEW TOLL EXCHANGE, LONDON.

SINCE the opening of the first Toll Exchange in Norwich Street, London, E.C.4, in 1921, the development of Toll traffic has shown a continuous increase. The facility provided by a plant capable of handling, on a non-waiting basis, telephone calls to and from subscribers within a radius of fifty miles of London, soon came into favour with the telephoning public. The growth of traffic through the Norwich Street Exchange has more recently been of the order of twenty per cent. per annum, and the consequent steady addition of lines brought into this exchange to meet traffic requirements has absorbed the whole of the accommodation available. During the summer of 1925, an extension of 25 positions was installed, but this was merely to meet immediate demands.

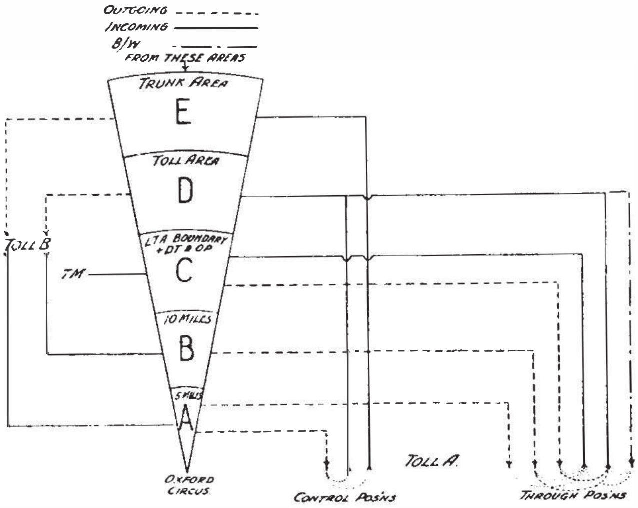


Fig. 1.—Toll Traffic Scheme, London.

Meanwhile, consideration had been given to increasing the capacity of the Toll handling equipment and it was decided that the most effective means of achieving this would be by building a new exchange to deal with outward Toll traffic from London, reserving the Norwich Street plant for inward Toll business.

Such an exchange has now been completed and was opened for service at 2 p.m. on Saturday, the 3rd December, 1927, with 796 junctions from and to London local exchanges and 743 lines to the Toll area, the latter number being mainly circuits transferred from Norwich Street.

The new exchange, known as "Toll A," is situated in the General Post Office (South) building in Carter Lane, E.C.4, and is a distance of half a mile from the Norwich Street premises now known as "Toll B."

Method of Routing of Toll Traffic.

A brief description of the method of routing traffic through the new Toll Exchange may now prove of interest. It will be recognised from what has already been said that the Norwich Street Exchange is interdependent in this consideration of the routing adopted.

The present incidence of Toll traffic in the London zone is defined in annular areas centred around Oxford Circus, and the diagram, Fig. 1, indicates the routing of the various classes of such traffic.

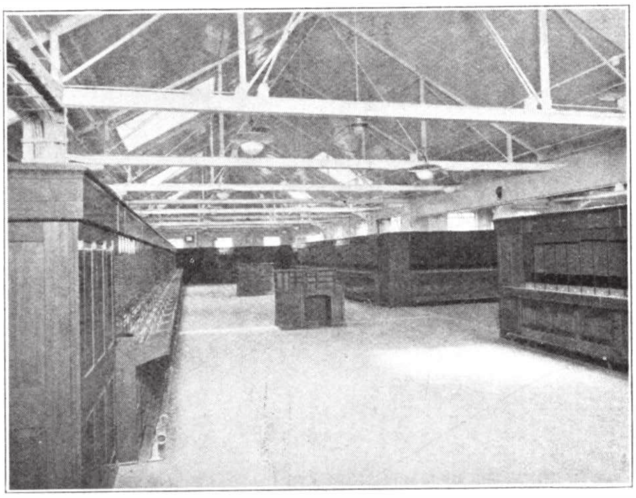


Fig. 2.—Main Switchroom.

The new exchange, Toll A, receives on "Control" positions, where the telephonists prepare the tickets and control the connections, all calls from within the five mile circle to exchanges in the D area and to certain centres in the E area.

The traffic from the A area to the C area, from the B to the C and D areas and from the C to C and the D areas is handled on "Through" positions, the ticketing of the calls being done at the originating exchange. Calls between D

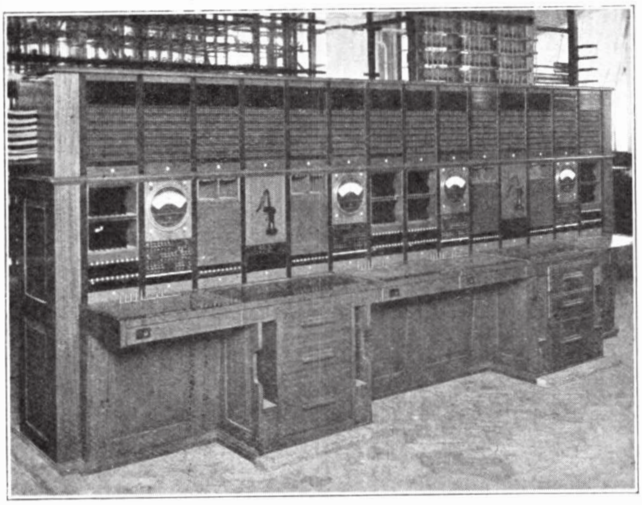


FIG. 3.—TEST DESK.

area exchanges where direct lines are not provided are also dealt with on the Through positions, bothway circuits being available in these cases.

Conversely calls from the D area to exchanges within the ten mile circle are passed through Norwich Street (Toll B), while calls from the C area to these same exchanges are routed through Tandem.

A number of groups of Provincial circuits hitherto terminated in the Trunk Exchange has been transferred to Toll A, thus virtually extending the Toll area. The exchanges concerned are Aldershot, Camberley, Chatham, Horsham, Leigh-on-Sea and Southend.

There is also connected to the new Toll Exchange a circuit to each of certain Trunk centres in the Home Counties where there is sufficient Toll to Trunk traffic to justify direct lines. Such places are Cambridge, Canterbury, Hastings, Ipswich, etc.

When through any abnormal circumstances, such as pressure of traffic, breakdown, etc., delay arises in completing connections on a Toll route, the calls are passed by order wire from the regular position to a Delay position where the telephonist tickets the calls and completes them seriatim as reverted calls, as is done in Trunk procedure.

DESCRIPTION OF THE EQUIPMENT.

The switchrooms in the new exchange occupy the whole of the fifth floor of G.P.O. (South), a space of 8,250 square feet. Fig. **2** is a view of a part of the main switchroom.

The I.D.F., apparatus racks, power distribution and fuse board are accommodated in a room on the fourth floor, while the test desk of four positions, Fig. **3**, and M.D.F. are on the ground floor.

Power is obtained from the Central Exchange main 24-volt batteries, which have been increased in capacity, and from smaller subsidiary cells (1000 A.H.) to provide a voltage of 30 for line signalling purposes on the Toll cord circuits. The City Exchange main battery in the same building has also been increased in capacity and is available in case of emergency for Toll use.

It may here be mentioned that the old charging plant in the City power room has been replaced by a motor-generator of modern type fed from the 440-volt., 3-phase supply, and giving an output of 1200 amperes at 37 volts. A small motor-generator worked off the same supply has also been provided to charge the subsidiary 6-volt. batteries already referred to. In the Central power room the existing 1000-ampere generator has been retained, but the motor has been replaced by one similar to that provided in the new motor-generator in the City plant.

The switchroom equipment comprises 158 Control positions, 29 Through positions, 2 Delay positions, 1 Service and 1 Fault position. All sections are of the standard C.B. No. 1 type of framework.

There are also a 14-position Information Desk, Fig. **4**, a service observation desk, five supervi-

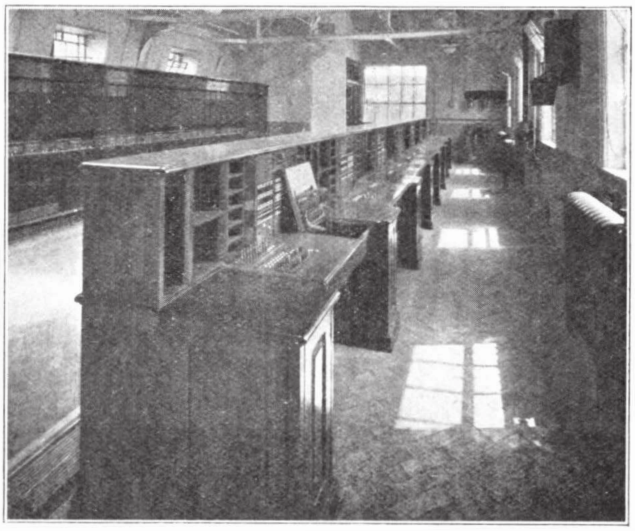


FIG. **4**.—INFORMATION DESK.

sors' desks and a meter cabinet for registering effective and ineffective calls.

CONTROL POSITIONS.

The Control positions, a section of which is shown in Fig. **5**, and a rear view in Fig. **6**, have an equipped capacity for 1,580 jack-ended junctions from London exchanges in the A area, a six-panel multiple of 2,800 jacks covering lines to the C, D and E areas, service circuits and miscellaneous lines to the Information Desk. Each position is provided with ten cord circuits, each cord circuit being fitted with speaking and ringing key, time check key, supervisory lamps and a time check lamp. There are 40 order wire keys for Toll and C area groups and service lines and two keys for effective and ineffctive metering. Each position is fitted with a Veeder clock immediately behind the register keys.

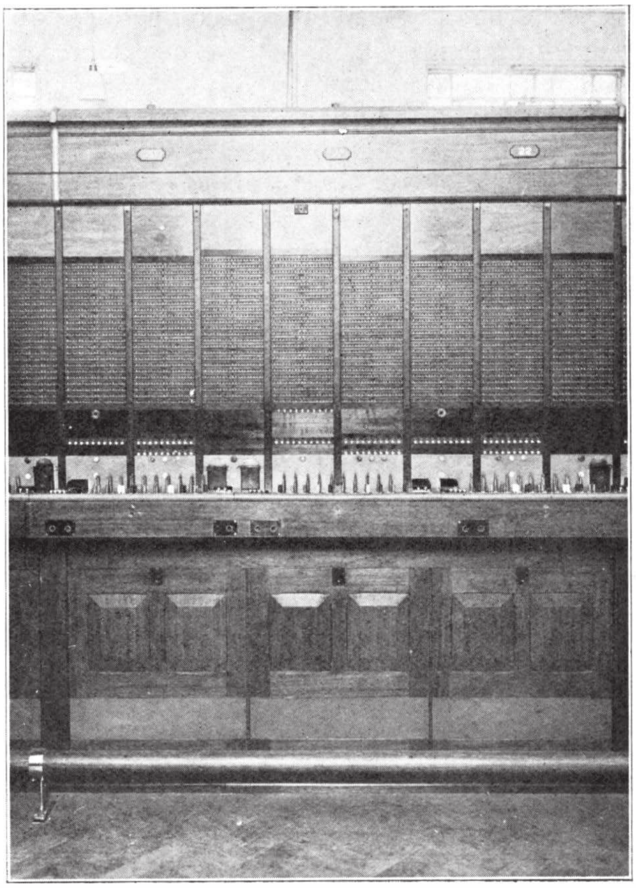


FIG. **5**.—TYPICAL SECTION, "CONTROL" POSITIONS.

These clocks are of compact construction and project through the keyboard displaying the time in figures through a small rectangular aperture, similar to that of the ordinary exchange meter. The clocks are electrically driven from a master clock with six-second propulsion through groups of relays.

It may here be mentioned that ordinary electrical display clocks are fitted in the switchrooms, but are driven from the main master clock for the building, thus providing an alternative time service in the event of failure of the Veeder clocks.

The time check circuit is given in Fig. **7**. The time checks, of which 1,600 are equipped, consist of two relays ST and D, the former operating contact springs and the latter a driving pawl somewhat similar to that in the ordinary subscriber's meter. The time checks are of a very compact type and are mounted on racks in the apparatus room with the L and K relays referred to in the diagram.

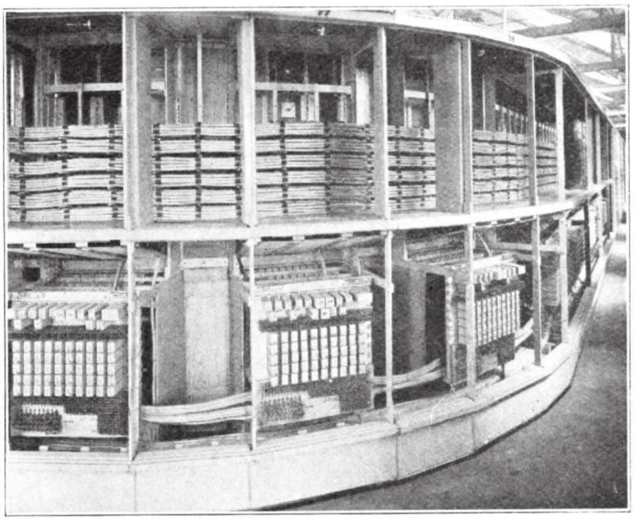


FIG. **6**.—REAR VIEW OF CONTROL POSITIONS.

To operate the time check the telephonist pushes forward the time check key of the cord circuit associated. This key, which is of the lever type, provides the battery for energising the ST coil and also completes the seconds impulse circuit from the master clock referred to in the description of the Veeder clocks. The ST coil, through the movement of its armature, closes the springs above that coil and at the same time operates the pivoted lever, which disconnects the lamp circuit and closes the driving circuit through the other set of springs

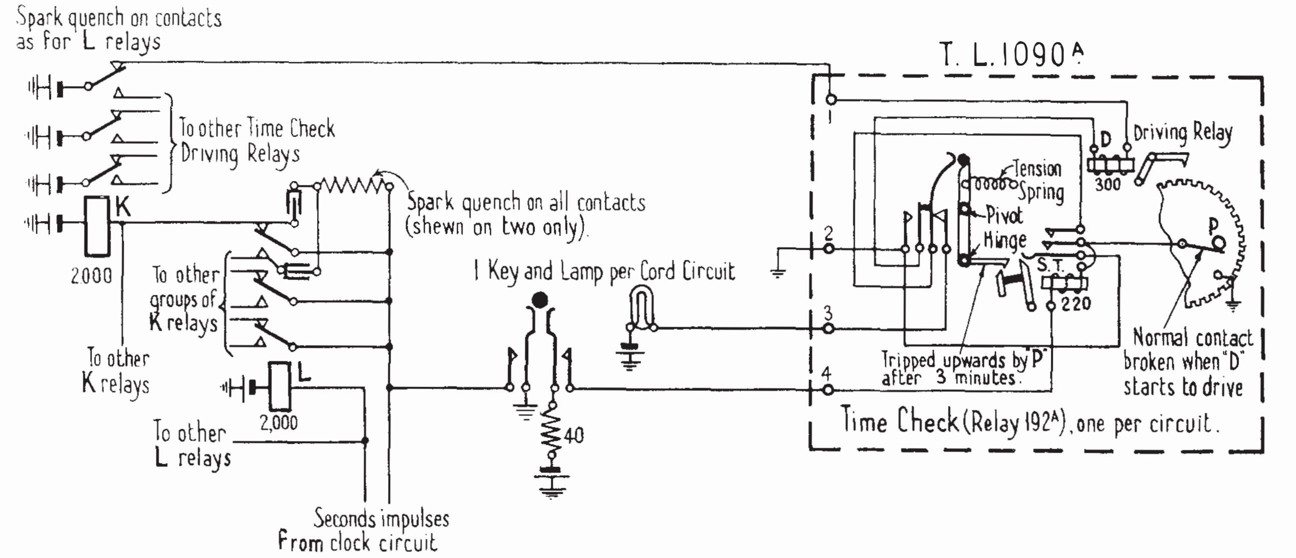

Spark quench on contacts as for L relays
To other Time Check Driving Relays
K
2000
Spark quench on all contacts (shewn on two only).
To other groups of K relays
To other K relays
L
2,000
To other L relays
Seconds impulses From clock circuit
1 Key and Lamp per Cord Circuit
40
T. L.1090A
1
2
3
4
D
Driving Relay
300
Tension Spring
Pivot Hinge
S.T.
220
P
Tripped upwards by "P" after 3 minutes.
Normal contact broken when "D" starts to drive
Time Check (Relay 192A), one per circuit.

Fig. 7.—Time Check Circuit.

shown in the diagram. D is then energised by means of the seconds impulses received from the contacts of the K relay associated and the toothed wheel steps in unison. At the first step the original earth connection is broken at the P spring on the wheel train, but ST remains energised through the earth provided on its own springs. At the end of the 180 impulses (3 minutes) the projection on the wheel trips the hinged lever upwards and knocks the bottom pawl away from the toothed wheel. The springs associated with the lever and the toothed wheel restore to normal. The armature of ST, however, is still operated and the time check lamp lights. To operate the time check for a further three minutes period, the key is momentarily restored to normal to allow the armature of ST to fall back and thus reset the time check. The earth on the P spring is to ensure that the time check will only operate when the driving wheel is in its normal position.

Besides the usual panel pilot lamp, there are on the Control positons an Instruction circuit pilot and a Register pilot. Accessories such as a ticket holder and tray for each position and a spring ticket clip in front of every cord circuit complete the key and cord shelf equipment.

Each of the incoming junctions is provided with an ancillary answering equipment, the primaries being in the 2nd, 5th and 7th panels of each section and the secondaries in the 1st, 4th and 6th panels. To avoid congestion only five jacks in each strip of ten primaries are used, the remaining five being in another strip below with diagonal displacement. The panel arrangement is clearly shown in the photograph, Fig. 5.

Night concentration equipments for 330 of the incoming circuits are also provided on a suite of 45 control positions. The night concentration jacks are on the 1st and 4th panels of these sections. The black keys seen in Fig. 5 above the incoming primary jacks are the concentration keys and are of the usual plunger type.

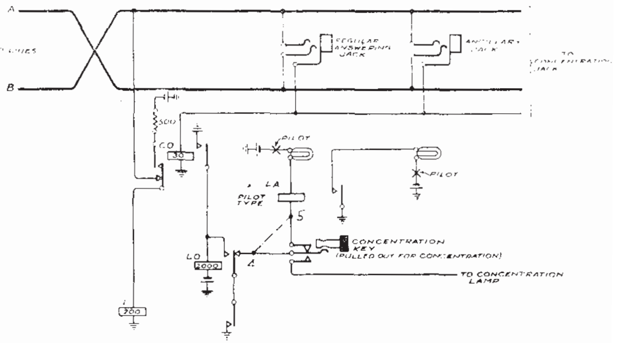


Fig. 8.—Control Positions—Incoming Circuits from C.B. and Auto-Manual Positions. (C.B. 1278).

Fig. 8 gives the calling equipment for a junction incoming from a C.B. exchange or automatic exchange manual board, and Fig. 9 the circuit for an incoming junction dialled out from an automatic exchange. In both cases the ancillary and concentration facilities are shown and in Fig. 9 provision is made for giving ringing tone back to the calling subscriber.

The object of the 20000 ohms resistance across the 4 m.f. condenser in the latter circuit is to maintain a " wet " condition at the contacts of the CO relay during conversation.

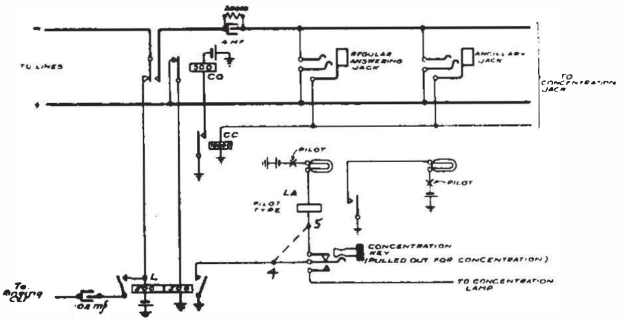


FIG. F.—CONTROL POSITIONS—INCOMING CIRCUITS DIALLED OUT FROM AUTO EXS. (C.B. 1279).

When regular answering circuits are terminated on positions which are also used for concentration the key shown in Figs. **8** and **9** is omitted, together with the concentration jack, and terminals numbered 4 and 5 are strapped together. This remark applies to the other jack-ended junction terminations to be described.

The regular, ancillary, concentration and auxiliary calling equipments have been separately wired as units to the I.D.F. to facilitate rearrangement arising from constantly changing conditions at distant exchanges.

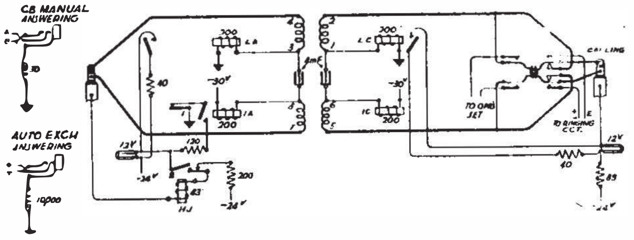


FIG. **10**.—CONTROL POSITIONS—CORD CIRCUIT. (C.B. 1276).
Answering C.B. Manual—Toll Ex. Control.
Answering Auto dialled out—Toll Ex. Control and Operator hold.

The cord circuit used on the Control positions is given in Fig. **10**. It shows the relays operating the supervisories, HJ and LA, when the cord circuit is used to answer a C.B. manual exchange and IA when the subscriber at an automatic exchange to which the cord is connected has cleared, HJ and LA not being actuated. In the latter case the 4 μF. condenser shown in Fig. **9** prevents the operation of LA and the metering relay at the automatic exchange.

The current flowing through relay IA when the subscriber hangs up operates the holding relay at the automatic end.

30-volt. line signalling with condensered repeating coils and balanced impedance coils and relays is used.

THROUGH POSITIONS.

The Through positions (Fig. **11** shows a section) have equipments for the accommodation of 870 jack-ended junctions, and are not provided with ancillary terminations. These will carry circuits incoming from the A, B, C and D areas. As in the case of the Control positions the jacks and calling lamps occupy only the alternate positions in each strip, two strips of 10 jacks and lamps being provided on most panels and on certain panels, three.

Night concentration equipments, 600 in all, are fitted for that number of incoming circuits on ten of the Through positions.

The outgoing Toll and service multiple is a continuation of that on the Control positions.

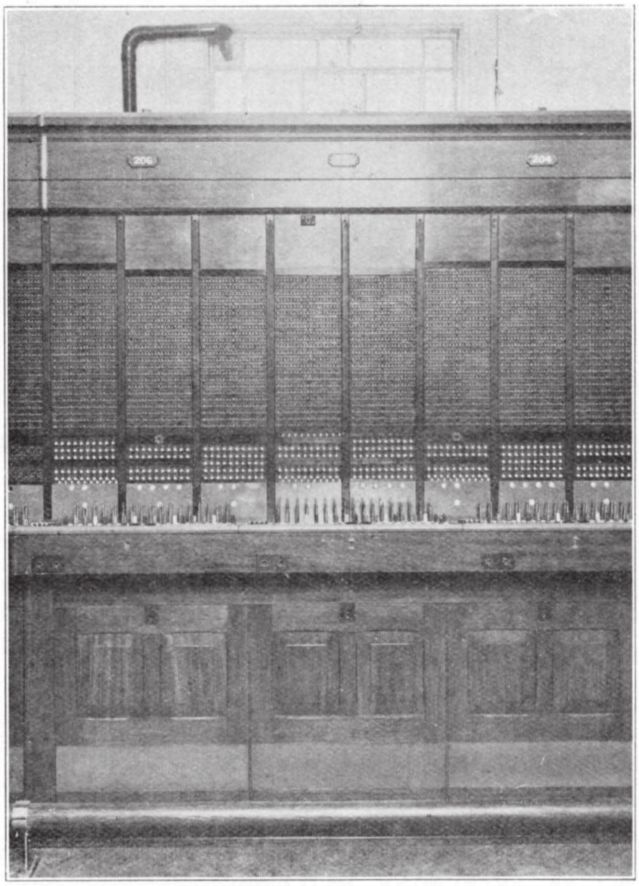


FIG. **11**.—TYPICAL SECTION, " THROUGH " POSITIONS.

The keyboard equipment consists of 17 pairs of cords with speaking and ringing keys, and register keys. No provision is necessary for Veeder clocks, time check keys and lamps and ticket trays.

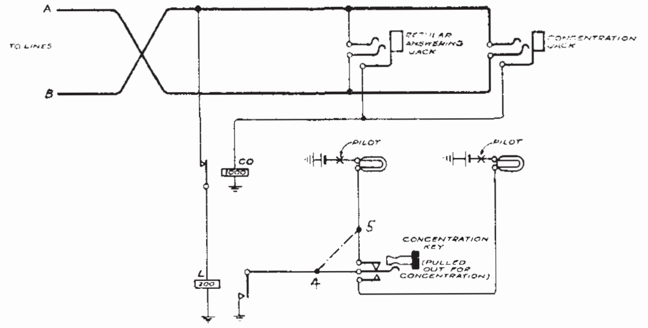


Fig. 12.—Through Positions—Incoming Circuits from C.B. Exchanges. (C.B. 1281).

Fig. 12 gives the calling equipment for the incoming circuits terminated on the Through positions and Fig. 13 the circuit for the termination on these positions of the bothway lines. 300 bothway auxiliary equipments have been provided.

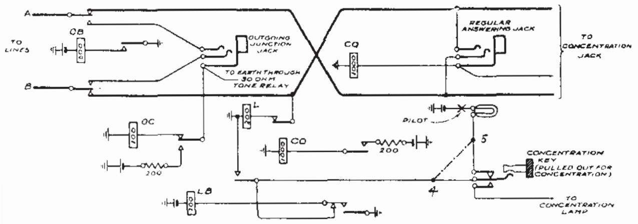


Fig. 13.—Through Positions—Bothway Circuits to C.B. Exchanges. (C.B. 1280).

It will be seen in both Figs. 12 and 13 that an incoming call is indicated through the medium of relay L, but in the case of the bothway circuit the sleeve connection of the cord circuit plug energises CQ, then LB which connects the battery for the engaged test on the bushes of the outgoing junction multiple jacks. On the other hand if the circuit be taken for an outgoing call, relays OC and OB switch away the line from the incoming equipment.

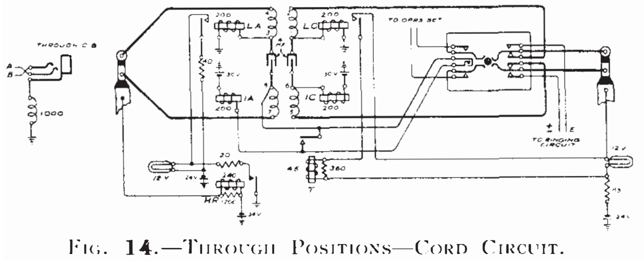


Fig. 14.—Through Positions—Cord Circuit. (C.B. 1289). Answering J.E. Junctions, through signalling, distant control.

The cord circuit used on the Through positions is that shown in Fig. 14. The arrangement provides for through operation of the supervisory signals from the distant Toll Exchange by means of relays LC and T.

Fig. 15 gives the cord circuit provided on the Service and adjacent position and on the Fault position. It is of a universal type and combines the facilities available in the Control and Through position cord circuits.

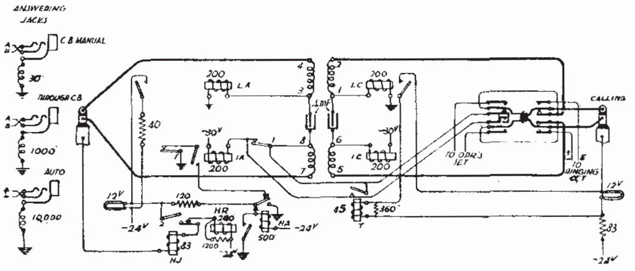


Fig. 15.—Universal Cord Circuit—Service and Circuits. (C.B. 1259).

Plug-ended Order Wire Junction Positions.

A suite of eleven positions will be equipped very shortly with 30 plug-ended junctions per position for use in connection with incoming order wire circuits. These lines will be from London and Toll area exchanges where the groups of lines are sufficiently large to justify order wire working. Fig. 16 indicates the circuit termination to be provided. The manual ringing key is provided for emergency purposes.

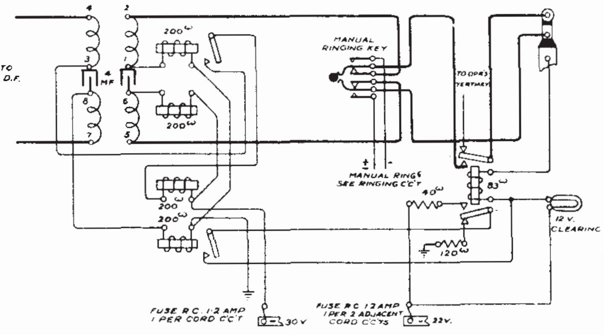

TO M.D.F.
200ω
MANUAL RINGING KEY
MANUAL RINGS SEE RINGING CCT
40ω
83ω
12 V. CLEARING
120ω
FUSE R.C 1.2 AMP 1 PER CORD CCT
30 V
FUSE R.C 1.2 AMP 1 PER 2 ADJACENT CORD CCTS
32 V.

Fig. 16.—Incoming Plug-ended Order Wire Fault Positions. (C.B. 1277)

Outgoing Toll Multiple; Group Engaged Tone.

Fig. 17 shows the arrangement provided in connection with the outgoing Toll multiple to give group engaged tone. In previous installations having this facility special jacks, one to each group of five multiple jacks, have been necessary to supply the engaged tone. This was to prevent interference between the engaged tone and plugging-up tone. In the new Toll Exchange, however, the whole of the actual multiple jacks are utilised in the arrangement illustrated, the bush of the first jack in the group of five being the one to have tone connected to it when all the five circuits are engaged. Interference between the tones has been avoided by providing special plugging-up cords for use in the first jack of a group.

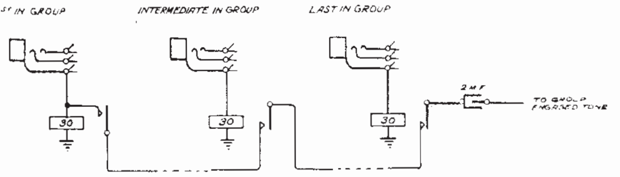


FIG. **17**.—GROUP ENGAGED TONE CIRCUIT.

ROUTE INFORMATION CIRCUITS.

In order that the telephonists on both the Control and Through positions may rapidly obtain information as to the routing of calls two route information enquiry circuits have been provided from all positions to the Information Desk. The circuits are terminated on two operator's instrument jacks at the rear of the desk and are also multipled on a lamp and jack equipment on each of the 14 positions of the Desk.

To deal with route enquiries expeditiously the circuit arrangement provides to meet three conditions of traffic: (*a*) Both circuits may be used on a ring-down basis, any operator on the desk taking the calls. This is usually during the slacker periods of the day and at night. (*b*) One operator, at the rear of the desk dealing with route enquiries only, is able to take both circuits by plugging her telephone set into the instrument at the rear of the Desk. (*c*) Two such operators at the rear of the Desk may take one circuit each at periods of pressure.

Fig. **18** gives the circuit arrangement of the route information equipment. Each main switchboard position has two keys in the order wire group, one black and the other white, marked Inf. The depression of either key operates relay G through contact G3, and if the circuit is not already occupied at another position, that is, there is no earth on the test wire, the earth connection shunting relay B is removed at G3 and B operates in series with G. The operator's telephone circuit is now connected through B1 and 2 to contacts 1 and 2 of relay O, which is energised when the telephone plug is in the instrument jack already referred to at the rear of the Information Desk, conditions (*b*) and (*c*).

It will be noticed that the depression of the Inf. key also puts an earth through contact B3 on to the test wire, which serves to prevent a second operator entering the same circuit.

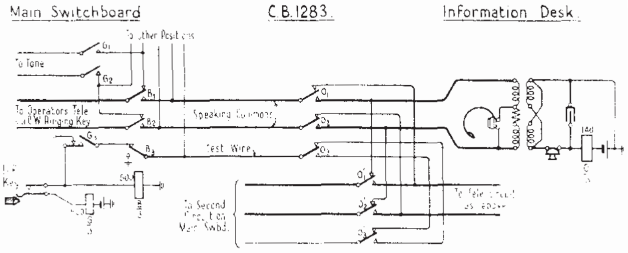


FIG. **18**.—ROUTE INFORMATION CIRCUIT.

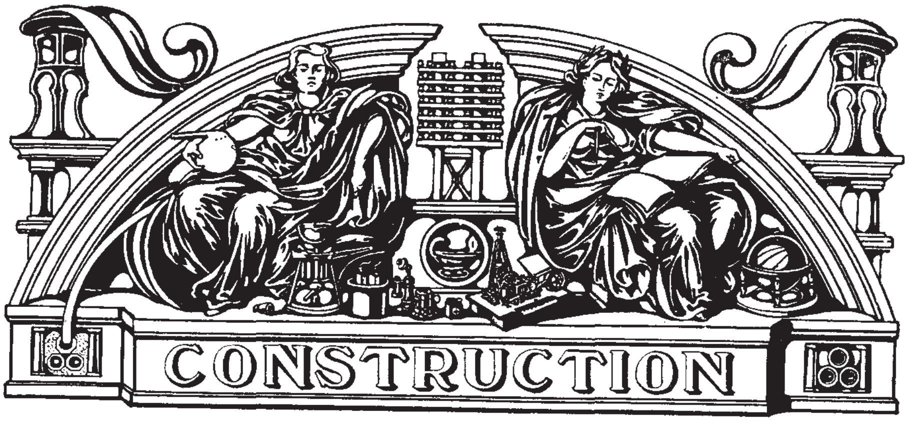
Had the route information circuit been engaged, however, an earth connection would have already been on the test wire and the B relay would not energise. In such circumstance, tone *via* the springs of relays B and G would be received by the calling operator.

If one telephonist only is in attendance at the rear of the desk and, therefore, the relay O in circuit No. 1 only is actuated, it will be evident from the diagram that enquiries on circuit No. 2 will come through to the first operator, the two circuits being connected in parallel by the contacts of O in line No. 1.

When the second route enquiry operator inserts her instrument plug the second O relay is energised and separates the two circuits and their test wires.

The whole of the circuit arrangements and lay-out of equipment was designed by the Post Office Engineering Staff. The installation, together with the enlargement of the charging plant, was carried out by Messrs. The Standard Telephones and Cables, Limited, who have kindly provided the photographs illustrating this description.

WM. D.



THE POST OFFICE (LONDON) RAILWAY.

SOME years ago, when traffic conditions were nothing like so bad as they are at present, the British Post Office came to the conclusion that it would be desirable to replace the road-van service it was then using by a more up-to-date method of transporting the letter and parcel mails between the principal post offices and railway stations in London, with a view both to accelerating the service and contributing to the reduction of the street congestion. A committee was therefore appointed in 1909, to consider the question in all its bearings; it decided that the best results would be obtained by employing an automatic system with electrically-operated trains without drivers, control being effected from special cabins at the various stations along the line. A scheme embodying these ideas was accordingly prepared in detail, the first contracts were let, and the tunnelling work was started just after war broke out. This world catastrophe naturally necessitated a change in policy. It was decided, however, to complete the tunnelling. No further progress was, however, made until after the Armistice, the tunnels being meanwhile employed for storing works of art.

Soon after the end of the war, tenders were invited for the electrical equipment of the railway, the specifications laying down a complete scheme but permitting alternative proposals to be put forward. The prices ruling at that time were, however, such to render it probable that, if the tenders received were accepted, the cost would adversely affect the economic soundness of the scheme; and it was not until 1924, therefore, when costs had fallen considerably, that contracts were placed for the electrical equipment, rolling-stock, conveyors, lifts and other necessary apparatus.

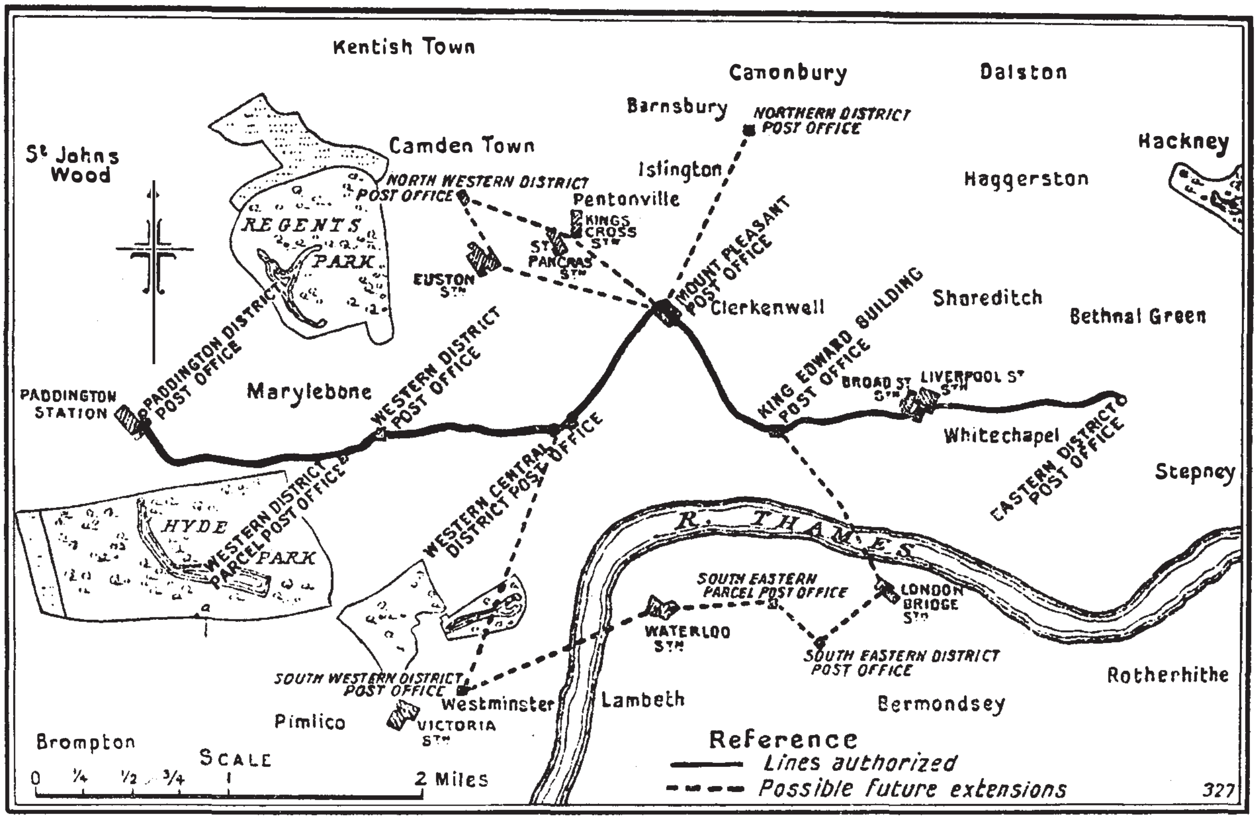
It may be mentioned here that the consulting engineer for the civil engineering work and the track construction of the railway was Mr. Harley H. Dalrymple-Hay, M. Inst., C.E., of Regent Street, London, a similar function for the equipment being exercised, first by Sir John Snell, G.B.E., until his appointment as Electricity Commissioner, and then by Mr. A. M. Sillar, M. Inst., C.E., of Victoria Street, Westminster. Major H. C. Gunton, M.B.E., Principal Power Engineer of the Post Office, representing Col. T. F. Purves, O.B.E., Engineer-in-Chief, has, in conjunction with Mr. Sillar, been responsible for the electrical equipment, rolling-stock, conveyors and lifts. To these gentlemen, and to Messrs. W. H. Powell and J. R. Kingston, we wish to express our thanks for their assistance in the preparation of this article.

Mr. Evan Evans, whose services were temporarily placed at the disposal of the Postmaster-General for the purpose by the London Underground Railways, occupies the position of Manager of the railway, and amongst other improvements, which were incorporated at his suggestion, was the employment of the containers, described later. Major W. G. Carter, M.C., of the Post Office Engineering Department, is the Executive Engineer, and is responsible for the maintenance of the Railway.

The extent of the railway, which is now running, is shown on the accompanying map (Fig. 1); the total length, as at present constructed, is 6½ miles.

Tenders for the necessary civil engineering work were invited in 1912, the contract for the tunnelling being let to Messrs. John Mowlem and Company, Limited, and for the station platform construction and permanent way to Messrs. Charles Brand and Son, both of London. Tunnelling was actually commenced on October 16th, 1914, and finished, except for certain works at Mount Pleasant car sheds, and at Paddington and Liverpool Street, in 1917. The station platform and permanent way contract was commenced in December, 1925. Before going into details, it may be as well to make a general statement on certain factors which determined the civil engineering construction of the railway.

FIG. 1. **ROUTE OF THE POST OFFICE TUBE.**



The gauge that would most conveniently carry rolling-stock of sufficient capacity to handle the required traffic is 2 ft.; this is the first permanent 2-ft. gauge railway in this country. The minimum size of the tunnel between the stations, which would accommodate a single track of this gauge and give the necessary clearances, was one of 7-ft. internal diameter. In order, however, to economise expenditure, it was decided to run both tracks in one tunnel between the stations. The minimum size tunnel requisite for this purpose on straight runs, and assuming that no curves would have a less radius than 400 ft., was one of 9-ft. internal diameter. This gave the necessary clearances, and was therefore the size finally chosen. As, however, at the stations the platforms are of the "island" type, like those of the tube railways, two tunnels were necessary, and 7-ft. tunnels were, therefore, constructed for a short distance from the end of each station tunnel to the commencement of the 9-ft. tunnel, the connection between the two diameters being made by step-plate junctions. In the stations themselves, accommodation had to be provided, not only for the platform line, but for a through line, and at the West Central District Office, Mount Pleasant and King Edward Building for a running round loop line as well, making three tracks in all. At these three-track stations, the internal diameter of the station tunnel is, therefore, 25 ft., while at the other stations it is 21-ft. 2½ in. To provide for sliding and loop connections it was also necessary in some cases to construct tunnels varying from the standard diameter of 9 ft. up to 19 ft., and even from 10 ft. to 25 ft.

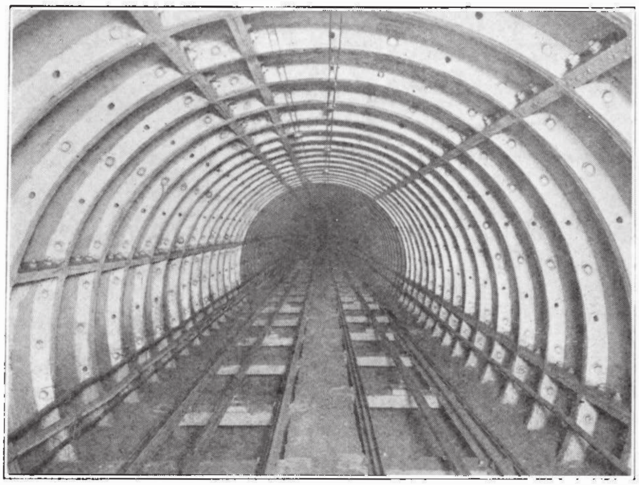


FIG. 2.—DOUBLE TRACK IN 9 FEET TUNNEL.

Generally speaking, the running tunnels, of which an illustration is given in Fig. 2, between the various stations were driven by the ordinary method of the Greathead shield. The short lengths of tunnels forming the station were excavated by hand mining, a method which presented no difficulty in the London clay. After excavation, the whole of the work was grouted with pure Portland cement.

In addition to the tunnel proper, permanent shafts were provided at all stations for giving access to the platforms, by means of conveyors, lifts and staircases, from the basement level of the various Post Office buildings and main line railway stations. These shafts generally have an internal diameter of 12 ft. They are of the usual construction, and were sunk by underpinning and lined with cast-iron segments. At Mount Pleasant and King Edward Building, which are two of the busiest stations on the railway, some of the shafts are 14 ft. in diameter.

Intercommunication between the island platforms is obtained by cross-passages of 10ft. internal diameter, while other works include the lay-by sidings at each end of the stations at Paddington, King Edward Building, and the Eastern District Office, as well as at the eastern end of Mount Pleasant station.

Coming to the track, the running rails are of British standard section No. 35, weighing 35 lbs. per yard, and are secured to oak sleepers by ¾ in. coach screws. This heavy design has been adopted, in order to reduce the maintenance work. The sleepers themselves are embedded in the concrete of the tunnel invert and are 3 ft. 6 in. long, their section being 7 in. by 3½ in. Great attention was paid to the question of curvature. On the running round loops the minimum radius of curvature is as low as 60 ft.

Dealing now with the electrical equipment, it may first be mentioned that the main contract for this important portion of the railway was let to the English Electric Company, of London. The E.H.T. and L.T. cables, other than those incorporated in the Control System, were supplied by the British Insulated Cables, Ltd., as sub-contractors. The track equipment proper, for which Messrs. Robert W. Blackwell and Company, Limited, of London, were sub-contractors, includes a mild-steel conductor rail of channel section, weighing 15 lb. per yard, which was supplied in 30 ft. lengths. Its conductivity is 1.8 microhm per yard. The conductor rails are supported on insulators, placed about 8 ft. apart, so that the upper surface of the rail is 3 in. higher than the face of the track rails, and the contiguous lengths are secured to each other by tapering steel fish plates 12in. long, by ¾ inch thick, by ⅞ inch wide at the top and 1¾ inch wide at the bottom. Ramps are provided at all places where the conductor rails are discontinuous, these being formed by bending down the conductor rail 1½ in. in a length of 1 ft. 6 in. In the platform sections the conductor rails have a lead of 2 ft. 6 ins. over the track sections, so as to allow sufficient braking distance and to ensure that the train comes to rest in the centre of the platform berth.

At places where the conductor rail is interrupted continuity is ensured by the use of 0.1 sq. in. jumper cables, which are fixed so that all live metal is kept clear of the track foundation and track rails. Two sizes of solid head bonds are used. Those for the track rails have a span of 7⅞ in. between the bond hole centres and those for the conductor rails one of 14 in. In both cases the bonds are of the standard flexible type. Two bonds are used for each conductor rail joint. The track rail, in addition to being bonded at the joints, are cross-bonded at intervals of about 100 yards by means of special bonds, which are connected to the cast-iron tunnel.

The conductor rails are divided into sections and one of the track rails is track-circuited throughout to form a control section. In order to increase the capacity of the earth return, with a view to keeping within the drop of pressure recognised by the Board of Trade, bare copper cables are laid throughout.

Supplies of electricity for operating the traction and other equipment on the Railway are drawn from the mains of the City of London Electric Lighting and the Charing Cross and City Electric Companies, the point of entry in both cases being a sub-station adjoining the Post Office sub-station at King Edward Building. These supplies form part of the electricity taken from the undertakings by the Department for general power and lighting purposes, and are given on the three-phase system at a pressure of 11,000 volts. and a frequency of 50. This pressure is stepped down to 6,600 volts by a bank of three 1,000 kV.-A. single-phase transformers with a total capacity of 3,000 kV.-A. which are installed in the sub-station we have just mentioned. The 6,600 volt. side of these transformers is connected to duplicate 'bus-bars, change-over switchgear being provided, so that the supply may be taken from one or other of the two undertakings in alternate months. The duplicate 'bus-bars in King Edward Building are connected to the Post Office sub-station at Mount Pleasant, where the 'bus-bars are in duplicate, by 0.1 sq. in. feeders, which are in triplicate. A supply is also given from the King Edward Building sub-station through two 0.0225 sq. in. three-core cables to the railway sub-station at Liverpool Street and from Mount Pleasant, through two 0.06 sq. in. three-core cable, to the railway sub-station at the Western Parcels Office. At Mount Pleasant the converting plant is accommodated in an existing sub-station. In other cases the traction equipment is placed in the invert of the large tube which forms the railway station. The feeders are protected by an overload circuit breaker at each end.

In each traction sub-station the 6,600 volt three-phase supply is first converted to direct current at 440 volts. For this purpose two sets of the 133-kW. single-phase transformers are used, making a 400-kW. bank, which is connected in delta on the E.H.T. side and in six-phase star on the low-tension side. This bank is connected to a 400-kW. rotary converter. The rotaries are shunt-wound and are fitted with commutating poles and damping windings. They are self-synchronising, and a pony motor is used for starting. There are sixteen of these sets in all, and they were all manufactured by Messrs. Newton Brothers (Derby), Limited.

A supply to the motors for operating the lifts, conveyors, and ventilating plant and the lighting circuits is also given from the 440-volt 'bus-bars, either direct, in the case of the stations where there are sub-stations, or through 0.5 sq. in. mains and distribution switchboards. Finally these two sets of 'bus-bars are connected through a 0.5 sq. in. and 0.1 sq. in. cable respectively to the 440-volt and 150-volt sections of a contractor rack, from which 0.1 sq. in. and 0.04 sq. in. cables supply the different sections of the conductor rail in that railway station zone.

The rolling stock consists of steel motor wagons, which are made up into trains of two or three wagons. Each wagon is capable of carrying a load of 1,120 lb. The electrical equipment of these wagons is simple, consisting principally of two 22-h.p. 440-volt, direct-current series motors, which are connected permanently in parallel. It also includes a resistance in series with each motor, which is permanently in circuit, and a set of electrically-operated braking equipment and reverser. The whole of the operation of the trains is automatic, control of the starting and stopping being effected from switch cabins at each station. No drivers are required.

The wagon motors are energised in the ordinary way from the conductor rail, which is divided into sections, each section being controlled either by automatic track circuits on the sections between the stations or by levers working under track circuit control in the station areas. These levers are concentrated in the various switch cabins. To start the train, its proper route is set up, as described hereafter, and the conductor rail is energised at 440 volts, so that it runs off down a falling gradient. The same pressure is employed on the conductor rails through the tunnel, the maximum speed reached being about 35 m.p.h. When the station is approached, the train enters a section on a rising gradient in which the conductor rail is dead, and is brought to rest by the automatic operation of the brakes. After a short interval the conductor rail in this section is energised at 440 volts and remains energised at that voltage for a predetermined time, which is sufficiently long to give the train a good start. At the end of this period the voltage is reduced to 150 volts, and the train runs into the station under this pressure. Here it either enters a dead berth section and is brought to rest by the brakes alongside the appropriate platform, or passes on to a through section, if it is not to stop at the station.

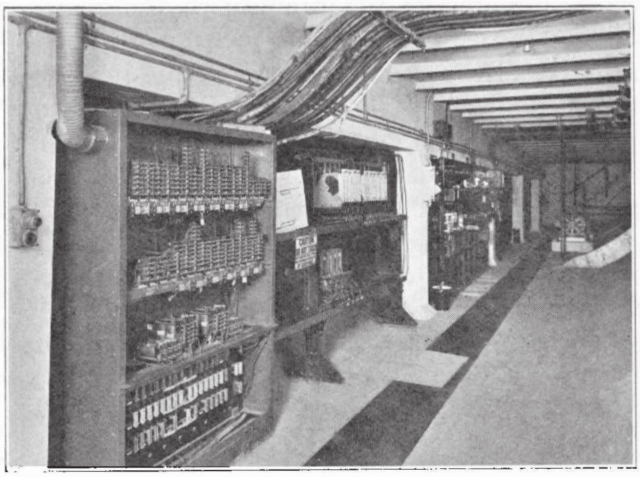


FIG. 3.—RELAY CABINET CONTACTOR RACK AND DISTRIBUTOR BOARD.

Operation in and out of the sidings is effected at a pressure of 440, 250 or 150 volts, this depending upon the lay-out of the siding and its approach.

The relay cabinets and contractor racks holding the gear (see Fig. 3) for operating the various circuits are placed in the tunnel inverts under the station. It will be convenient here to say something further about their operation.

When the route lever is pulled to the point-operating position, current is supplied to the point contactor coils. This causes the point contactor to operate and to close the 150 volt circuit of the point motor. On completion of the point movement the circuit through the point detector contacts is closed, together with the corresponding coil of the point detector relay, thus closing all the contacts in circuit, which require proof of the reversal of the points.

The operation of the track circuiting system, by means of which current is supplied to the conductor rails in the tunnel sections, may be explained briefly as follows:—When the train enters section A, that is, the first automatically operated section, it causes the track relay A to be picked up. This open-circuits stick relay AS which drops. The train passes on to section B, stick relay BS being dropped in a similar manner. Track relay A drops as soon as the train leaves section A. With track relay A down, track relay B up, and stick relay BS down, the AS stick relay is reset, provided that the power contactor supplying section A is open. The power contactor for Section A will not be closed until stick relay BS has been reset by the train running on to section C. If a train runs on to a particular track without operating it for any cause, the stick relay of the section behind will not reset, thus providing protection for the train ahead.

As the train approaches a station it runs off the last automatic section on to a braking section. This is on a rising gradient, so that the brakes are assisted by gravity in bringing the train to rest. The length of this section is sufficient to ensure that this happens under all conditions. It has been found that at any particular station the time which it takes for a train to come to rest does not vary very much. It is therefore possible by experiment to select a time which gives a little margin during which it is quite certain that the train will stop in the braking section. This time may be called the braking time. When it has come to rest in the braking section, the control of the train is assumed by camshaft control gear of a pattern very similar to the equipment used on the English Electric Company's electric locomotives. (See Fig. 4).

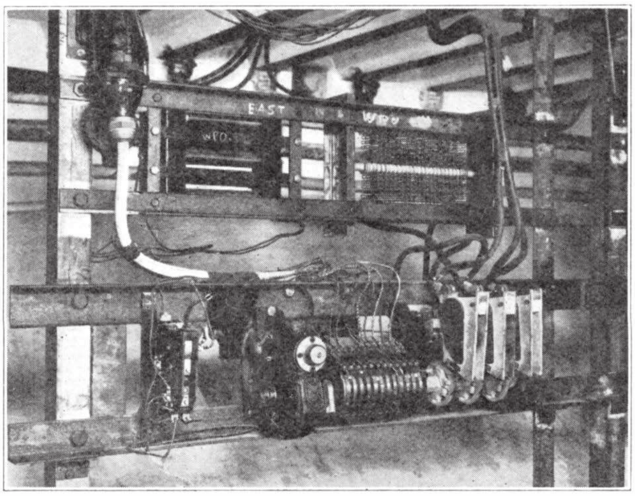


FIG. 4.—CAMSHAFT GEAR.

Fig. 5 shows a three-wagon train, such as will form the normal traffic unit, being loaded at a station. The bodies of these wagons were manufactured by the Kilmarnock Engineering Company, Limited, and the electrical equipment by the English Electric Company, Limited.

As regards design, great care has been taken to ensure easy access to all parts, and to admit of the rapid inspection and replacement of such important portions as the motors, wheels and axles, journal boxes, brake gear and collector shoes. The general dimensions of the wagons are: Total length of body, 12ft. 6in., total length over buffers, 13ft. 5in., total width over axle boxes, 3ft. 6in., and total height above rail level, 4ft. 11½in. The wheel base is 7ft. 3in., the diameter of the wheels, 2ft., while the gauge is also 2ft. The under frame of each wagon is of channel steel, the body being built up of steel angles securely braced and riveted together and secured to the underframe by bolts. The flooring sides and ends are constructed of mild open-hearth steel plates. The wheels have cast-steel centres and steel tyres. The diameter of the wheel over the tyre is 2ft. and the breadth of the tyre on the tread is 2½in. The axles on to which the wheels are pressed hydraulically are of acid open-hearth steel and are fitted with roller bearings. After assembly the wheels and axles were carefully balanced and tested to ensure that they run smoothly and without vibration at a speed of 500 r.p.m. The axle boxes are of the roller bearing type, and are self-lubricating and dustproof. The end thrust is taken by ball thrusts. The wagons are coupled by links which are fitted to spring buffers.

The collector shoes are carried on frames which are suspended from the axle boxes. The horn plates are of steel plate, their sliding surfaces, and the corresponding sliding surfaces of the axle boxes, being machined and arranged so that they can be lubricated. Two vertical helical springs are fitted over each journal to take the weight of the wagon body under all conditions of service. These springs are of acid open-hearth steel, and have been specially designed to render the running of the wagon as smooth as possible, both when empty and loaded, and to prevent undue pitching and rolling.

The two series motors receive their supply through two shoes, one at each end of the wagon. Reversal is effected by a hand switch which changes the direction of the fields. The negative brushes of each motor are connected to a common bar, which in turn is connected through the brake solenoid to earth. The equipment of the wagons forming one train are paralleled by means of a bus line and electrical couplers on the negative side of the permanent resistance.

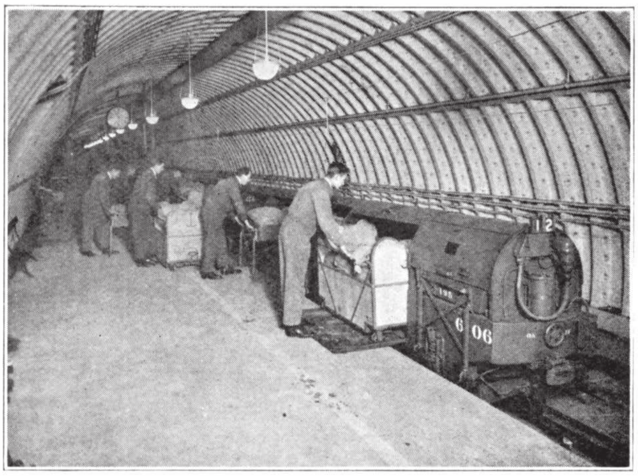


FIG. 5.—LOADING WAGONS.

When a wagon is standing on a de-energised track, no current passes through the brake solenoid and the springs therefore hold the blocks against the wheels. As soon as current is supplied to the conductor rail, the solenoid is energised, the brakes are released, and the motors start up, the current rush being damped by the resistances. On entering a dead section, current ceases to pass through the solenoid, and the brakes are immediately applied.

This arrangement enables the direct-current series motors to be operated on what is virtually an alternating current characteristic when giving the specified output of 22 h.p. The arrangement has the great advantage, from the operating point of view, that as little as possible control equipment is carried on the wagons themselves.

Each motor is slung from the wagon axle in bearings, and from the wagon frame by springs. The motor is totally enclosed, and generally complies with the English Electric Co. standard design for traction work. The armature shaft bearings are carried outside the frame, and are of the roller pattern. Driving is effected through spur gearing of the single-reduction type, the ratio of reduction being 3.33 to 1. Like the motor the gearing is totally enclosed.

As already stated, it is proposed that the wagons shall be connected together in trains of three. For this purpose a twin-core train cable with a twin coupling at each end is used. Each core of this cable has a sectional area of 0.66 sq. in. The train couplings are interchangeable at both ends, and are fitted with a locking device so as to prevent them from working loose.

The loads on these wagons are carried in special containers, which have been designed so that they can be wheeled across the platforms. These containers are of two different types, depending on whether they are to be carried in the centre or side compartments of the wagon.

The mail bags are passed from the ground level to the railway platform with a minimum of human intervention, an extensive system of conveyors, elevators, spiral chutes and lifts; either individually or in combination. In general, it may be said that the lifts and elevators, combined with the conveyor, are used for the upward traffic and conveyors and spiral chutes for the downward. More particularly, conveyors are used for all the up traffic at Paddington and for the parcels at Mount Pleasant, and bag elevators combined with conveyors for the up traffic of letters at King Edward Building and Mount Pleasant.

When lifts are used, the bags are loaded into containers in the Sorting Offices, and are wheeled to the lifts by hand for the downward journey. At the railway platform level they are wheeled from the lifts by hand to the wagons where they are placed into position. (See Fig. **5**). The elevators, which are of the bucket type, are loaded by conveyors which are fed through hatches on the Post Office railway platforms. The bags are discharged from the elevators in the Post Office where the contents are deposited either on to a short conveyor or on to the floor level.

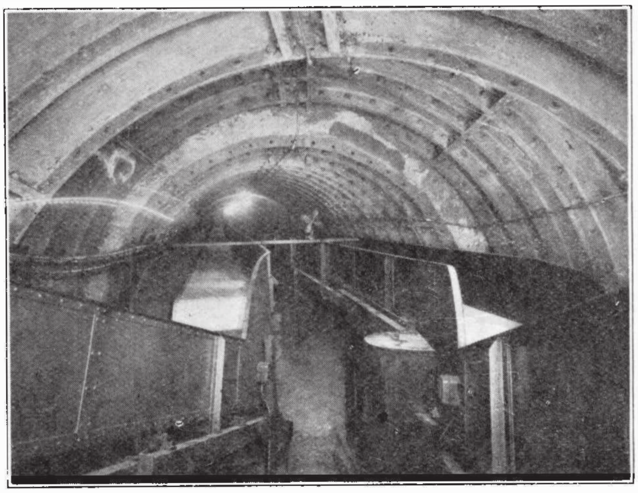


Fig. **6**.—Band Conveyors, Liverpool Street Station.

There are in all 21 band conveyors, five at Mount Pleasant, four at King Edward Building, seven at Paddington, and two at Liverpool Street, and one each at the Western, West-Central, and Eastern Post Offices. This excludes a number of short conveyors at various delivery points. Generally the construction of these conveyors is the same, and is shown in Fig. **6**.

At King Edward Building there is one 20 cwt. bag elevator, which also receives its load from the two under-platform conveyors, and delivers it on the ground floor of the building at a point in the lobby near the east loading platform. All the elevators consist of a number of sheet-steel buckets, which are connected to two parallel endless chains moving in steel guides, the shape of which determines the path of the bucket. The space between the buckets is filled in with stout rubber and cotton belting. At the top and bottom of the elevator the main chains pass round sprocket wheels, the bottom pair of which is driven by a motor through worm and spur gearing. This motor and the rest of the equipment is designed for continuous operation. The path of each elevator is at first horizontal, and then gradually changes to the vertical, the bags being loaded on when the elevator is in the former position.

Lifts are provided at all stations and are used for parcel traffic in both directions and letter traffic in an upward direction, except at King Edward Building and Mount Pleasant where band conveyors, elevators and spiral chutes are employed, the lifts being available in case of emergency. The total number of lifts in use at the various stations is 17.

As it is important that the air from the Post Office railway station should not escape into the post offices, a ventilating system has been provided, whereby a continuous down draught is exerted. The air is drawn over the plant, which is, as already noted, installed in the tube inverts, and thus exercises a cooling effect, finally it is exhausted into the open air.

At most stations there are either one or two inlet fans with a capacity of 1,100 cub. ft. per minute, but at the Western Parcel Post Office and at Liverpool Street there are two fans with a capacity of 4,500 cub. ft. per minute. The outlet fans are 4,500 cub. ft., 6,000 cub. ft., or 9,000 cub. ft. per minute in the capacity.

The ducts are constructed of 16 S.W.G. galvanised steel plate. Their area is such that the air velocity does not exceed 2,500 ft. per minute, and they are laid out so that sharp bends are avoided. Messrs. Davidson & Co. were the sub-contractors for this work.

JOINTING A.S.P.C. CABLE CONDUCTORS OF SMALL GAUGE.

A. Morris, M.I.E.E., and F. Stevens.

Synopsis.—An interesting account* was recently given of some of the difficulties which arise in connection with the splicing of overhead conductors. The present article deals with unsoldered twist splices in underground telephone cables containing light gauge conductors.

General.—This type of splice is used almost exclusively at the joints of local cables and trouble is occasionally experienced with it when the usual care has not been exercised during the constructional work. Although abnormally large values of conductor resistance, loop or unbalance, point unmistakably to defective splices in this class of jointing, yet imperfect joints are not always disclosed by the results of such tests. The passage of a current causes variations in the resistance of an imperfect joint. This is particularly noticeable in the case of very defective joints. If the current is increased the resistance will in general decrease; thus in the case of the joint referred to in Table No. 1 the resistance of one of the splices changed from 15 ohms to 3 ohms. In this manner faults arising from imperfect splicing may be temporarily removed. Ringing currents and relatively large direct currents in such circumstances usually produce these effects and it is for this reason that signalling over such faulty circuits is seldom interfered with. To weak alternating currents, however, such joints may offer a high impedance—*i.e.*, the resistance of the joint in such cases may be several times the value as measured with say a direct current of one milliampere—and for this reason speech transmission may be adversely affected.

It is not certain whether such changes of resistance are entirely of electrical origin or whether they are due wholly or in part to mechanical changes at the splice.

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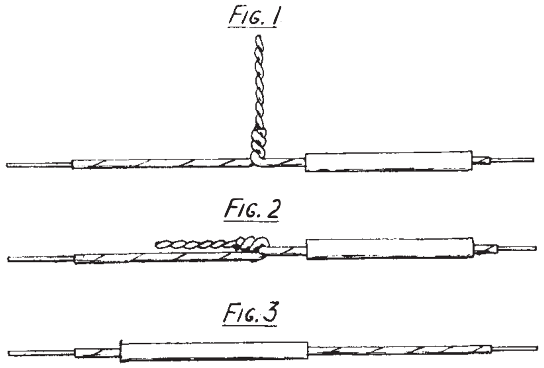
* *" The Telephone Plant Job of to-day," P. L. Johnson, " Telephony," Vol. 93, No. 7, August 13th, 1927.*

Visual inspection of a joint, when directed towards certain salient features which are described later, will often enable imperfect or defective splicing to be detected; supervision during construction should specially include this item of cable jointing work.



FIGS. 1, 2, & 3 - STANDARD METHOD OF TWIST SPLICING.

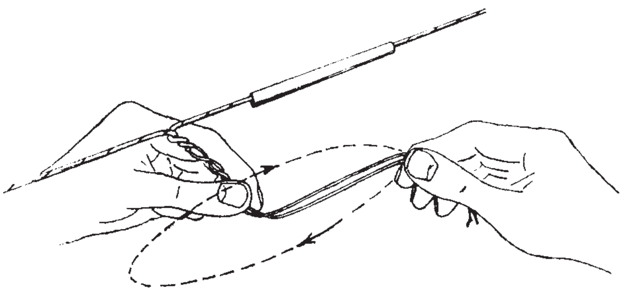


FIG. 4 - CRANK HANDLE SPLICE DURING TWISTING

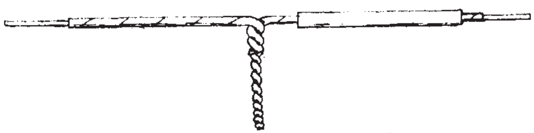


FIG. 5 CRANK HANDLE SPLICE
TWIST COMPLETED AND CUT TO LENGTH

Standard method of twist jointing.

The procedure described in British Post Office Technical Instructions XIV., Part 11, Section V (*b*), page 52, for the twist jointing of 6½ lb., 10 lb., 12½ lb., 20 lb. and 40 lb. cable conductors is as follows:—

(*a*) The two wires to be jointed, on which the paper covering and thread have been allowed to remain, will be twisted together for a few turns, a paper sleeve having first been slipped over one wire. The remainder of the paper and thread will then be removed.

(*b*) The bare conductors will be cleaned with glass paper and twisted together so that the copper joint is 1 inch in length. The joint will not be soldered, except in the case of 20 lb. conductors in Balanced Cables and all 40 lb. conductors, or unless it is to be covered with compound.

(*c*) The twisted conductors will be bent down and the paper sleeve drawn over the joint.

Figs. **1**, **2** and **3** illustrate a twist splice constructed as described above. It will be seen that this splice is characterised by tight, fairly close twisting, which is uniform from the tip to the twisted wrapped portion of the splice.

Crank-handle method of twist jointing.

This method of twist splicing is applied as follows:—

(*a*) The two wires to be spliced, on which the paper covering and thread have been allowed to remain are twisted together for one complete turn, a paper sleeve having first been slipped over one wire. The remainder of the paper and thread is then removed.

(*b*) The bare conductors are then cleaned with glass paper and twisted together thus:—With the left hand hold the two bare wires tightly between the thumb and forefinger at a distance of about one inch from the point at which the paper and string have been cut away. With the right hand, hold the two bare wires between the thumb and forefinger; turn the wires back between the two hands so as to form a crank-handle and rotate the right hand, at the same time permitting the twists to run through the left thumb and forefinger down to the insulated wires as in Fig. **4**. The wires are then cut so as to leave one inch of copper splice as in Fig. **5**.

(*c*) The twisted conductors are then laid back along the length of the joint and the paper sleeve drawn into position. It will be seen that a joint constructed according to this method is characterised by very close, tight twists at the tip, becoming less tight towards the twisted wrapped portion, in the immediate neighbourhood of which the twists are fairly open.

Each of the methods described, when correctly followed, produces twist splices of satisfactory electrical features.

General remarks on unsoldered twist-splices.

The magnitude of the resistance of a splice will depend upon the condition and area of the contact surfaces of the wires. With clean surfaces this resistance will be inconsiderable, even if the contact pressure and area are each small. If, however, the wires are coated or discoloured by an oxide film or are unclean in any other respect, the splice will be of high resistance unless the contact pressure and area are considerable.

In general the area of contact for tightly twisted wires will be proportional to the length of the copper splice. Owing to the thickness of the paper and thread coverings, there is a general tendency for the first two or three twists of the copper splice (beyond the twisted wrapped portion of the splice) to be imperfectly bedded upon each other. This in itself is not a serious objection since it lessens the strain and consequent chance of fracture of the wires during bending down for sleeving purposes. It results, however, in a diminution in the effective length of the splice, and if for any reason the standard length (one inch) of copper splice is reduced, *e.g.*, by maintaining the standard overall length, but increasing the length of the covered portion, or by inadvertently cutting the copper splice too short, or by opening the final twists through the use of blunted cutting pliers, a serious decrease in the contact surface will arise.

If the wires are twisted lightly together, multiple-point or line contact only will result, whereas with tight twisting, surface contact will be secured, owing to the resulting bedding action of the wires upon one another. Light twisting of the wires will generally give rise to a loose splice. The turning back of a joint for sleeving purposes whereby the wires become displaced relatively to each other is another cause of loose splices. This effect appears to be more pronounced in 20 lb. conductors than in 10 lb. conductors, probably because of their greater rigidity. The seasonal variations of temperature of telephone cables in this country is 14 to 15 degrees Centigrade: initial looseness in a splice is probably accentuated by subsequent movements due to such temperature changes, as well as by vibration.

Referring to the angle between two wires prior to twisting as the "Angle of twist," then the area of contact will increase as the angle of twist increases from a small angle up to about 80 degrees. Too small an angle of twist will be apparent on inspection by reason of the splice having too few turns. Such a splice will generally be loose. If the angle of twist is much greater than 80 degrees there will be a tendency for one wire only to rotate. Inspection in this case will reveal a splice of many turns which will generally be of irregular twist. Unless the twisting in this case is extremely tight, there is little bedding action and consequently inadequate area of contact surface whilst, in addition, the joint tends to become loose. Furthermore, such a splice will usually be bent, and broken line or surface contact will result from the accompanying imperfect bedding.

In making the crank-handle twist, if the wires are held too loosely between the fingers of the left hand, the twists become crowded together and are tightest immediately beneath the twisted wrapped portion—"organ-grinder" or "barrel-organ" twist. In such cases the wires when turned down for sleeving become strained and are liable to fracture.

Results of the examination of a defective cable-joint.

The following results were obtained by inspection on site and subsequent electrical test in the laboratory of 80 splices cut out of a 800/10 Twin A.S.P.C. cable joint.

Tests of the 80 splices with one milliampere in the line, showed that the resistance of each of 64 was less than 0.1 ohm, whilst the resistance of the remaining 16 ranged from 0.1 ohm to 7.7 (variable) ohms. Table No. (1) gives the resistance of each of these latter splices, allowance having been made for the resistance of the conductor on either side of the splice. The resistance of 2 yards of conductor is approximately 0.1 ohm. The Table also indicates the type of each splice as revealed by visual examination and classified in general accordance with the next paragraph.

TABLE I.

RESISTANCE (TESTING CURRENT 1 MILLIAMPERE) AND CLASSIFICATION OF DEFECTIVE TWIST SPLICES IN A 800/10 TWIN A.S.P.C. CABLE JOINT.

Splice No.	Resistance (ohms).	Type.	Splice No.	Resistance (ohms).	Type.
62	0.16	A B C F G	70	0.57	A B C . G
13	0.17	A B C F G	66	0.70	A B C . G
37	0.18	A B C . G	19	0.74	A B C F .
26	0.20	A B C . G	28	1.24	A B C F G
43	0.22	A B . . G	27	2.19	A B C F .
38	0.25	A B . G	17	3.0*	A B C F .
24	0.50	A B C . G	79	7.4*	A B C . G
67	0.53	A B . . G	48	7.7*	A B C . G

* Variable.

The more frequent causes of defective twist splices in practice.

From the foregoing, and apart from broken splices, these may be summarised as follows:—

(A) Non cleaning of the wires before twisting, whereby oxide films giving rise to discolouration of the wires, varying in shade from light straw to purple, constitute the actual surfaces of contact.

(B) Shortness of the copper splice. This will occur if the splice is cut too short, but is usually due to the paper wrapping being continued too far in the splice. The length of bare wire actually twisted together is thereby reduced and there is a consequent diminution in the area of contact. Figs. **6** and **7**.

(C) Looseness of the splice. This will be caused by one or other of the defects D, E, F, G, namely:—

(D) Light twisting. Fig. **8**.

(E) The effects of turning back for sleeving purposes. Fig. **9**.

(F) Too few twists, *i.e.*, too small an angle of twist. Fig. **10**.

(G) Bent splice. Fig. **11**.

Conclusions.

In order to avoid faulty twist splices the instruction relating to the method of making such splices should be exactly followed, particularly in respect of the cleaning of the wires and the length of the copper splice.

The loosening which may occur in a splice (which does not conform in all respects to the standard splice), when turned back for sleeving purposes, can be prevented as follows:—

Twist the paper-covered portion in the normal manner; twist the A wire one complete turn around the B wire; and then the B wire one complete turn around the A wire; finally, proceed with the normal twisting operation. This method will prevent the slack of one wire, arising from the turning back, from being transmitted through the splice. A splice of three diameters

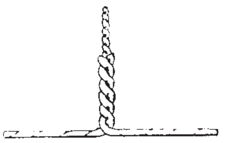


Fig. 6 Short copper splice - Paper continued too far.

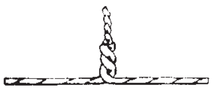


Fig. 7 Short copper splice - Wires cut too short.

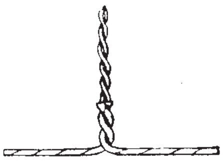


Fig. 8 Loosely twisted splice.

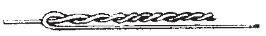


Fig. 9 Twist loosened and displaced in bending.

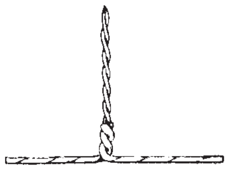


Fig. 10 Too few twists - Angle of twist too small.

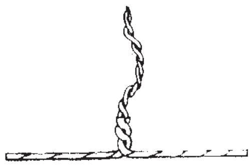


Fig. 11 Bent Splice

Examples of Deffective Twist Splices.

instead of one of two diameters results for part of the length of the splice and a slightly larger paper sleeve may be required. The special turns in question virtually replace non-effective twists of the standard method; no effective contact area is therefore lost and greater rigidity of the wires is secured.

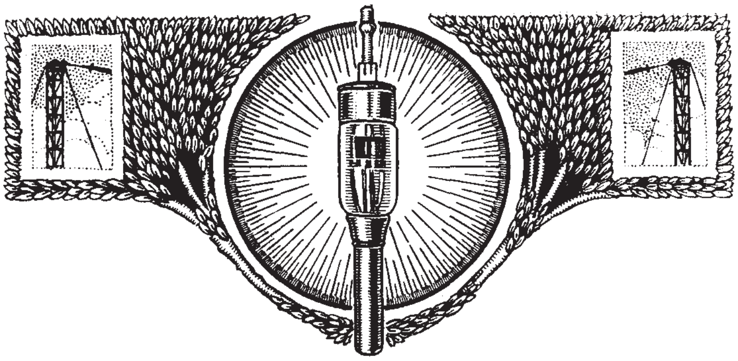
A loose splice seldom occurs when the crank-handle method has been adopted; incorrect procedure in this case, however, may give rise to too few effective twists at the tip, or to strained wires—with liability to fracture—in the neighbourhood of the wrapped portion of the splice.

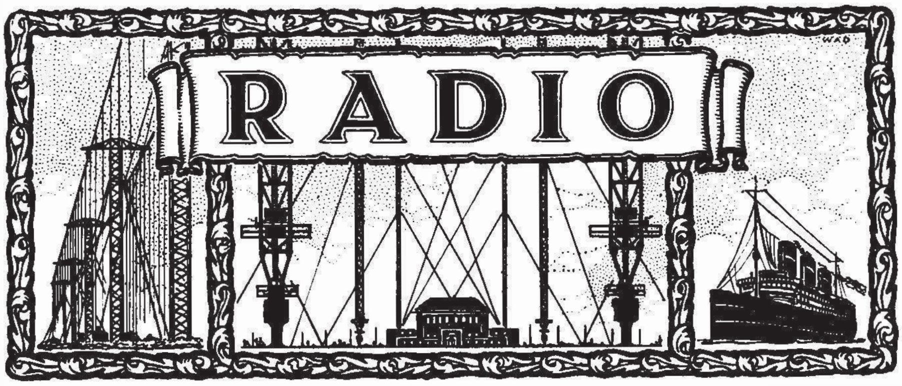
20 lb. conductors should be more tightly twisted than 10 lb. conductors, not only for the purpose of obviating the above mentioned loosening effect but also to increase the area of contact surface by reason of the bedding action previously referred to.

In order to secure a satisfactory twist the angle between the wires should be about 80 degrees. During the operation of cutting the splice to the required length, the wires should be pulled with a slight rotating action and then cut, so as to obviate opening the final twists of the splice.

Imperfectly made twist joints give rise to considerable maintenance difficulties, since for the reasons already given a circuit which appears from the results of an ordinary conductor resistance test to be quite good, or which gives good results immediately on switching, may be subject to serious deterioration as conversation over the circuit proceeds. Furthermore, if spurious resistances of various magnitudes are present at many cable joints on a circuit, attempts at localisation of the splices giving rise to the major faults are generally very unsatisfactory, whilst even if such attempts are successful the disturbance of any particular joint for the removal of a faulty splice on a particular circuit may precipitate faults in the splices of other circuits at that joint.

The authors are indebted to Mr. J. F. Doust for the illustrations.





HUMBER RADIO STATION.

L. J. Jones, A.M.I.E.E., and W. M. Osborn, A.M.I.E.E.

THE new "Humber" Radio Station equipped with up-to-date transmitting and receiving plant has been erected at Mablethorpe, Lincolnshire, and brought into commission for ship-and-shore communication in replacement of the old Station at Grimsby, which was closed down on December 6th last.

The old Station was erected by the Admiralty during the War and was transferred to the Post Office, together with Wick and Portpatrick Radio Stations, in 1920; it was housed in three passenger railway coach bodies placed end to end on West Pier, Grimsby, and was equipped with a 2 KW Spark Transmitter of naval type. Fig. 1 is a photograph of the old Station at West Pier, Grimsby.

The primary reason for closing down the old Station was the lack of accommodation required for the provision of the necessary plant to enable the station to function as a Direction Finding Station for ships in the Humber district. Pending the erection of the new Station the Direction Finding service for the Humber district was carried out for the Post Office by the Admiralty Station at Flamborough Head. A site near Mablethorpe was selected as the most suitable locality for Direction Finding operations and the new Station has been equipped with valve transmitting apparatus and Direction Finding plant, employing the Bellini-Tosi System, as adopted by the Department at other Coast Radio Stations.

The new Humber Radio Station has also been fitted with a Radio Telephony installation for communication with trawlers and is the first British P.O. Coast Station to be so equipped.

The following is a brief general description of the new Station.

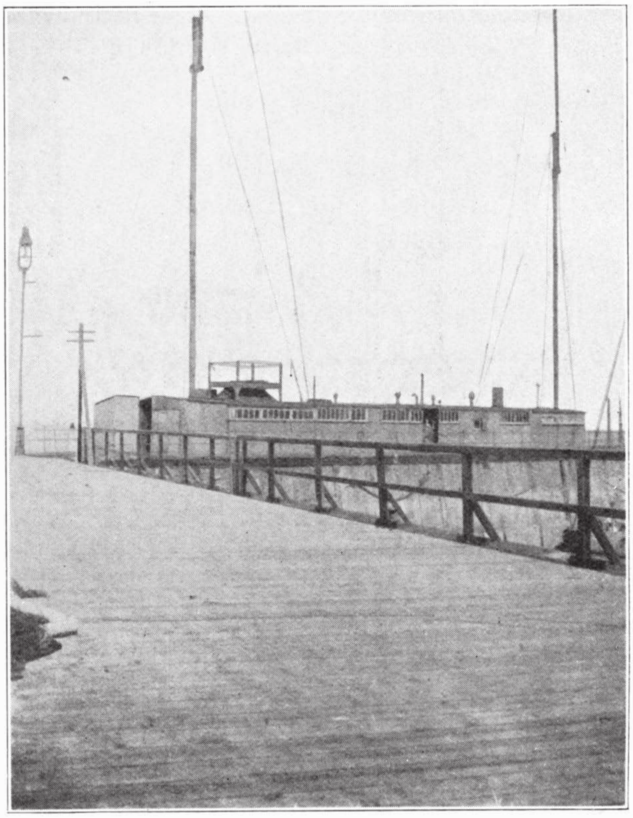


Fig. 1.—Old Station at West Pier, Grimsby.

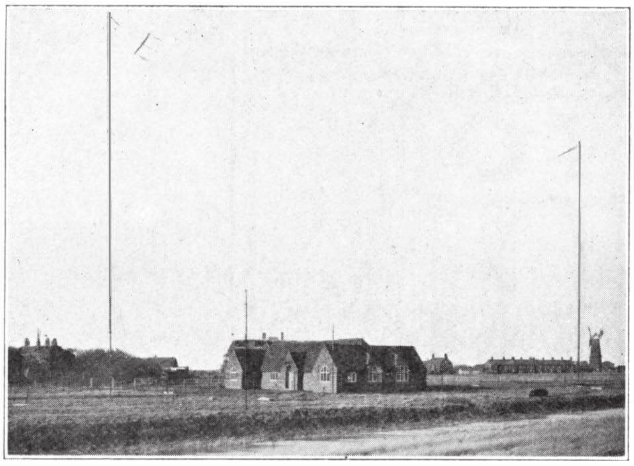


FIG. 2.—GENERAL VIEW OF BUILDINGS AND SITE.

Site and Buildings. The site, which is about 2 acres in extent, is situated at Trusthorpe, about a mile from Mablethorpe Railway Station, on land adjoining the sea shore. The buildings are of one story type and are erected approximately at the centre of the site. Fig. **2** is a general view of the site and buildings: Fig. **3** shows in plan the lay-out of the building and engineering plant.

Aerial and Earth Systems. The main transmitting aerial is of three wire "T" type, supported by two tubular masts, 120 feet high, consisting of 20 feet lengths of 4in. diameter steam tubing screwed together and stayed with six sets of stays at 20 feet intervals. The masts are erected 246 feet apart on a line running approximately North-South. A separate aerial of 6-wire cage type, approximately 70 feet long, and suspended from the top of the north mast is provided for short wave telegraphy and telephony.

The Direction Finding and main receiving aerial system, consisting of two triangular frames of approximately 95 feet sides and a base 160 feet long, is rigged beneath the main transmitting aerial and is symetrically disposed about the south mast. The triangular frames are erected at right angles to each other and are supported on the south mast with their apexes and base centres at points 82 feet and 10 feet above the ground, respectively, and at their lower corners by tubular jury masts 25 feet high. In order to maintain the electrical balance of the two triangular frames, the four lead-in wires from the centres of the bases are twisted as in ordinary telephone practice throughout their length between the south mast and the lead-in panel a distance of 110 feet. The wire used

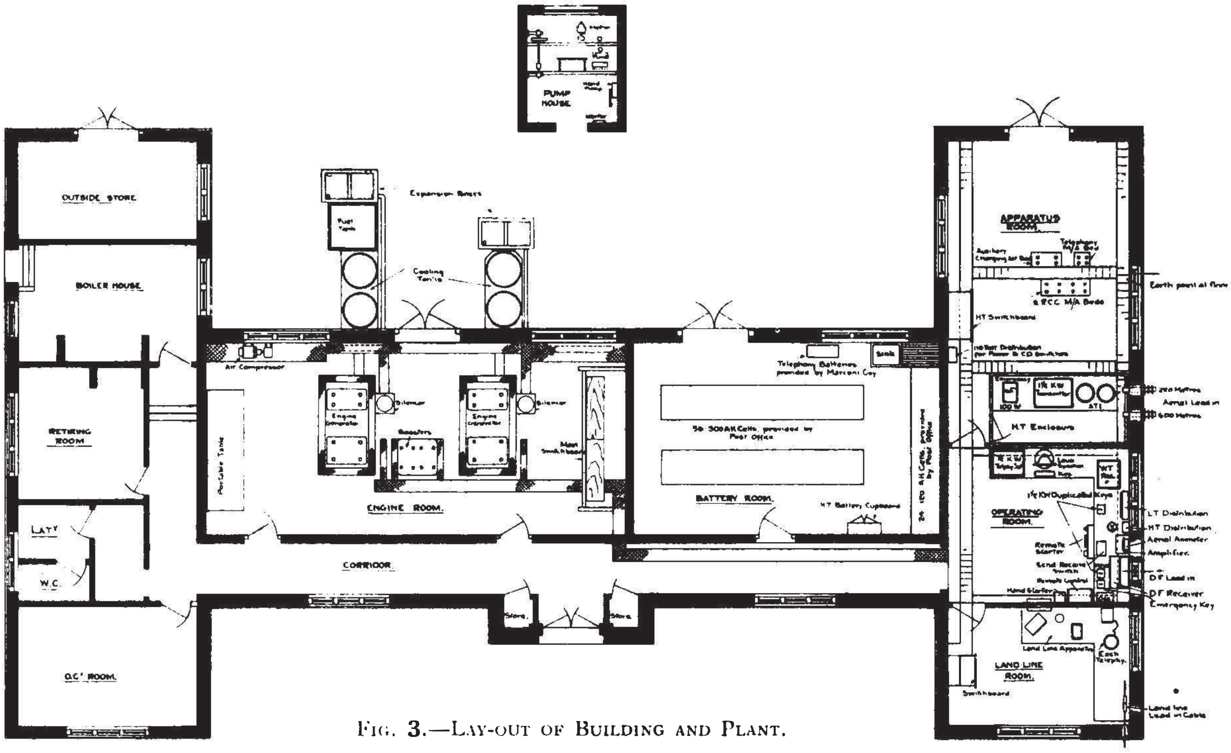


FIG. 3.—LAY-OUT OF BUILDING AND PLANT.

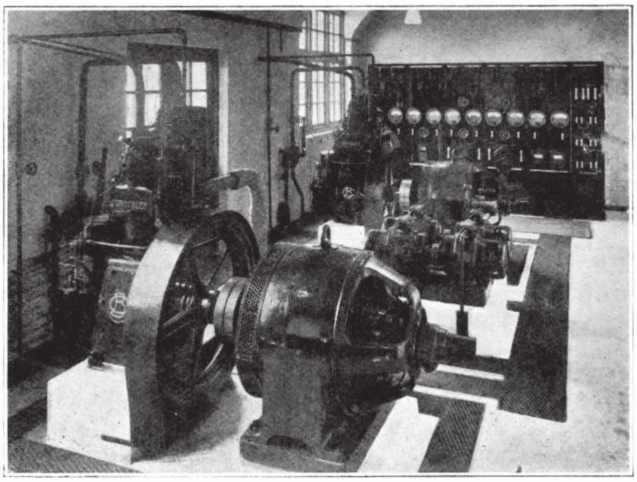


Fig. 4.—Engine Room.

throughout the construction of the aerial system is of " Wire, Bronze 7/19."

The main earth system is entirely underground and consists of 6ft. by 2ft. corrugated iron sheets, buried vertically with their long edges six inches below surface, and arranged in two semi-circles of 60 feet radius, symetrically disposed relative to the main earth point in the building, the sheets being connected thereto by equal lengths of " Wire Copper Soft 7/18 Strand." A separate earth system of similar type to the main system, but consisting of one semi-circle of 10 feet radius is provided for use in conjunction with the Direction Finding Receiver.

Power Plant. The electrical energy required for the operating and lighting services is generated at the Station as no public supply service is available.

The power plant was installed by the Austin Lighting Co., Ltd., and comprises two 14/16 H.P. Crossley Crude Oil Engines, direct-coupled to two 8 K.W. 110 Volt B.T.H. Generators for charging a Secondary Cell Battery of 56 cells of 300 ampere hour capacity, together with two 2 K.W. B.T.H. Motor Driven Boosters arranged for operation in association with the Generators so as to maintain the main bus-bars at a constant voltage of 110 volts under any condition of charge or discharge of the battery. Facilities have been provided for milking individual cells of the battery by means of either Motor Booster.

The Main Switchboard for controlling the above plant is of the enclosed type and comprises Generator and Booster Panels in duplicate, Battery and Feeder Panels.

Fig. 4 is a view of the Engine Room showing the Engine Generators and the Main Switchboard.

An Auxiliary Battery Charging Set and Switchboard is provided for use in connection with a battery of twenty-four Secondary Cells of 120 Ampere-hour capacity arranged and connected to the Switchboard in eight groups of three cells each; these Cells are used for heating the filaments of the Receiver valves and for power supply to the Emergency Transmitter. The Charging Set comprises a B.T.H. motor-generator, the motor of which is supplied with current at 110 volts from the main bus-bars; the generator provides for an out-put of 12 amperes throughout a range of 5 to 40 volts. The Switchboard is equipped with accessories for the control of the motor-generator and for the change-over of the groups of cells for charging or discharging.

Fig. 5 is a view of the Battery Room showing the main battery in the foreground, the auxiliary battery in the background and on the right of the figure, a cupboard containing a battery of 50 Leclanché cells used for providing the general high tension supply for the receiving plant.

Transmitters. The Transmitters were installed by the Radio Communication Co., Ltd., and comprise 1½ K.W. Main and 100-watt Emergency Valve Transmitters equipped for Continuous Wave and Interrupted Continuous

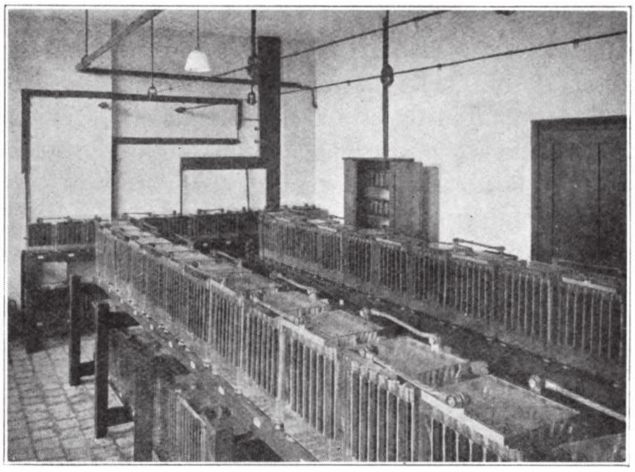


Fig. 5.—Battery Room.

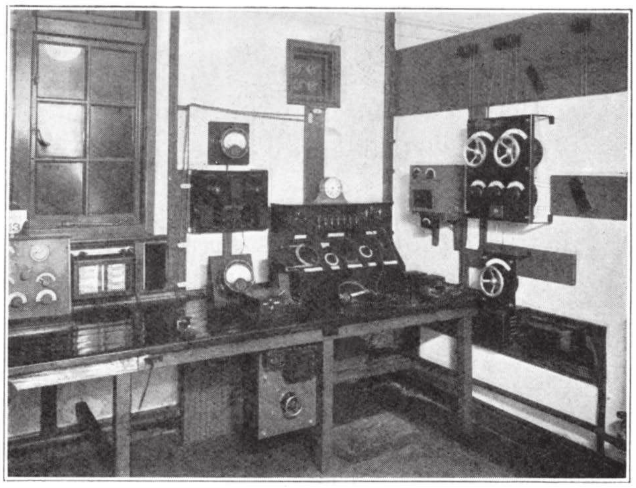


FIG. 6.—OPERATING BENCH.

Wave telegraphy. The Transmitting plant is similar to that installed at Seaforth Radio Station and is described in an article published in Volume 21, Part 1 of this Journal.

The transmitting apparatus is assembled on a bench in a high tension enclosure in the Apparatus Room as shown in Fig. **3**. The operation and all control of the transmitters are effected from the operator's position in the Operating Room, whence the Transmitters are under the observation of the Operator through the glazed partition which divides the Operating Room from the Apparatus Room.

Fig. **6** is a view of the operating bench in the Operating Room, showing on the right the Bowden wire control panels mounted on the wall and the Bowden wires running overhead to the H.T. enclosure. Fig. **7** is a view of the Apparatus Room, showing the rear of the transmitters with the protecting screen removed and on the right the power control panel.

Telephony Installation. A view of the telephony installation which is fitted in the Operating Room is shown in Fig. **8**. This comprises a self-contained transmitting and receiving set arranged for operation on the waves 200 and 220 metres. The apparatus is the Marconi Wireless Telegraph Company's standard "Type XMC 1 Telephone Set" slightly modified to suit Post Office service requirements; the normal rating of the Set is 500 watts.

Power for the Set is supplied by a motor-generator which is housed in the Apparatus Room and is seen in the foreground of Fig. **7**. It comprises a motor wound to suit the 110-volt D.C. supply of the station and a combined low tension and high tension D.C. generator delivering 14 amperes at 16 volts for charging a floating 12-volt battery which supplies current for the filaments of the transmitting and receiving valves, and 150 milliamperes at 2,500 volts for H.T. supply to the anodes of the transmitting valves.

The well-known choke control method of speech modulation is employed in the Set. The transmitting valves comprise one oscillator valve type T250 and one modulating valve type T400 m/a. The aerial is inductively coupled to the closed oscillatory circuit.

The set is designed for simplex working, the change from speech to listening being effected by the operation of a "Send-Receive" switch mounted on the face of the cabinet, which transfers the aerial from the transmitting to the receiving circuits. The receiver is a 4-valve set, comprising one stage H.F. amplification, one detector stage and two stages low frequency amplification. The valve filaments are all in series across the 12 volt filament battery; the first three valves are of D.E.R. type, the last is of D.E.6 type. Reaction is employed between the anode of the detector valve and the aerial. The telephone receiver is in the anode of the first L.F. valve and a Loud Speaker is joined in the output of the fourth valve.

Provision is made for Interrupted Continuous Wave telegraphy by means of a key controlled

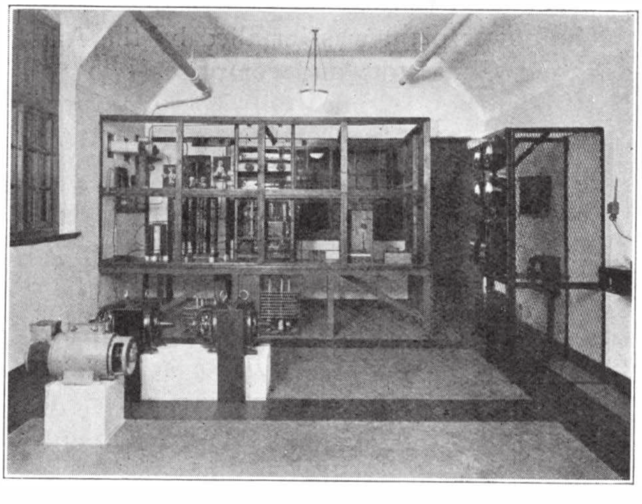


FIG. 7.—APPARATUS ROOM.

buzzer employed as a modulator in place of the microphone. The keying unit is visible in Fig. **8** immediately in front of the Loud Speaker.

Receiving Apparatus. Two complete receivers for the main 600 metre reception are employed and are both visible in Fig. **6**. The main receiver of the Station is the Marconi "Type 12A Direction Finding Receiver" seen on the right of the bench in the figure; the receiver seen on the left is of Post Office pattern, is non-directional in type and is only brought into use in the event of interruption to the D.F. Receiver. The 2-valve low frequency amplifier associated with the Post Office receiver can be seen mounted on the wall to the left of the D.F. receiver. An heterodyne oscillator is also associated with the D.F. receiver to enable the reception of C.W. signals.

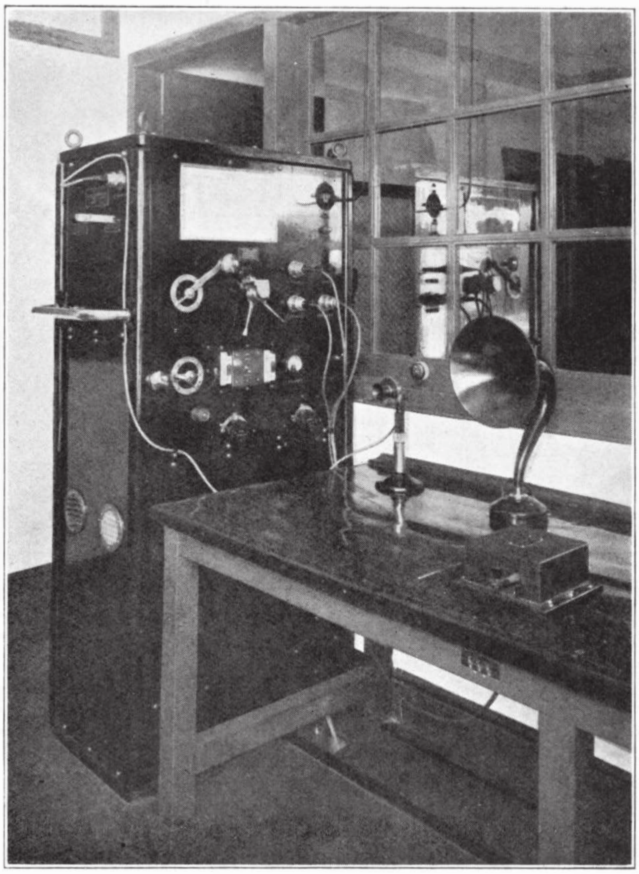


FIG. 8.—RADIO TELEPHONY INSTALLATION.

Special care has been taken in the lay-out of the cables between the filament lighting batteries and the sets with a view to avoiding inductive disturbance from the power plant, land-lines, etc. Two groups of 6-volt batteries are reserved exclusively for the D.F. receiver. These are connected to the Battery Charging Switchboard *via* two D.P.D.T. switches located in the Operating Room, and with the object of reducing the wire to earth capacity of the D.F. receiver filament leads to the lowest possible limit the cables between the D.P.D.T. switches and the set are not lead covered and are carried on a route as remote as possible from other current carrying circuits. For a similar purpose the H.T. battery for the D.F. set consists of a box of 50 "Cells, Dry X" placed on a shelf immediately underneath the D.F. receiver. The filament current for purposes other than D.F. in the Operating Room is effected from a "Board, Distributing, No. 10" to which the main supply from the Auxiliary Charging Switchboard is brought, and the General H.T. supply obtained from the Leclanché Cells in the Battery Room already referred to is distributed from a "Cut Out No. 1 $\frac{10}{10}$" fitted with dummy fuses.

A general diagram of the external connections of the receiving plant and its association with the various switches, the Telephony Transmitter and batteries etc., is given in Fig. **9**; from this figure the general interconnection of the various items of apparatus can be traced.

The "Directional—D.F. Switch" has segmental attachment to the Switch lever and is so placed relative to the D.F. Receiver that one half of the Radiogonimeter scale of the set is covered when the switch is at the "Directional" position. It is thus impossible for the operator to take a bearing unless this switch is at the "D.F." position, in which position it operates the Marconi Solenoid Switch thus disconnecting all other aerials to give the conditions necessary for the determination of true bearings.

The action of switching the "Normal-Telephony" switch to "Telephony" is to cause the operation of the Radio Communication Company's type Solenoid Switch, which transfers the short aerial from the main to the telephony set. It also breaks the main key circuit thus making it impossible to transmit

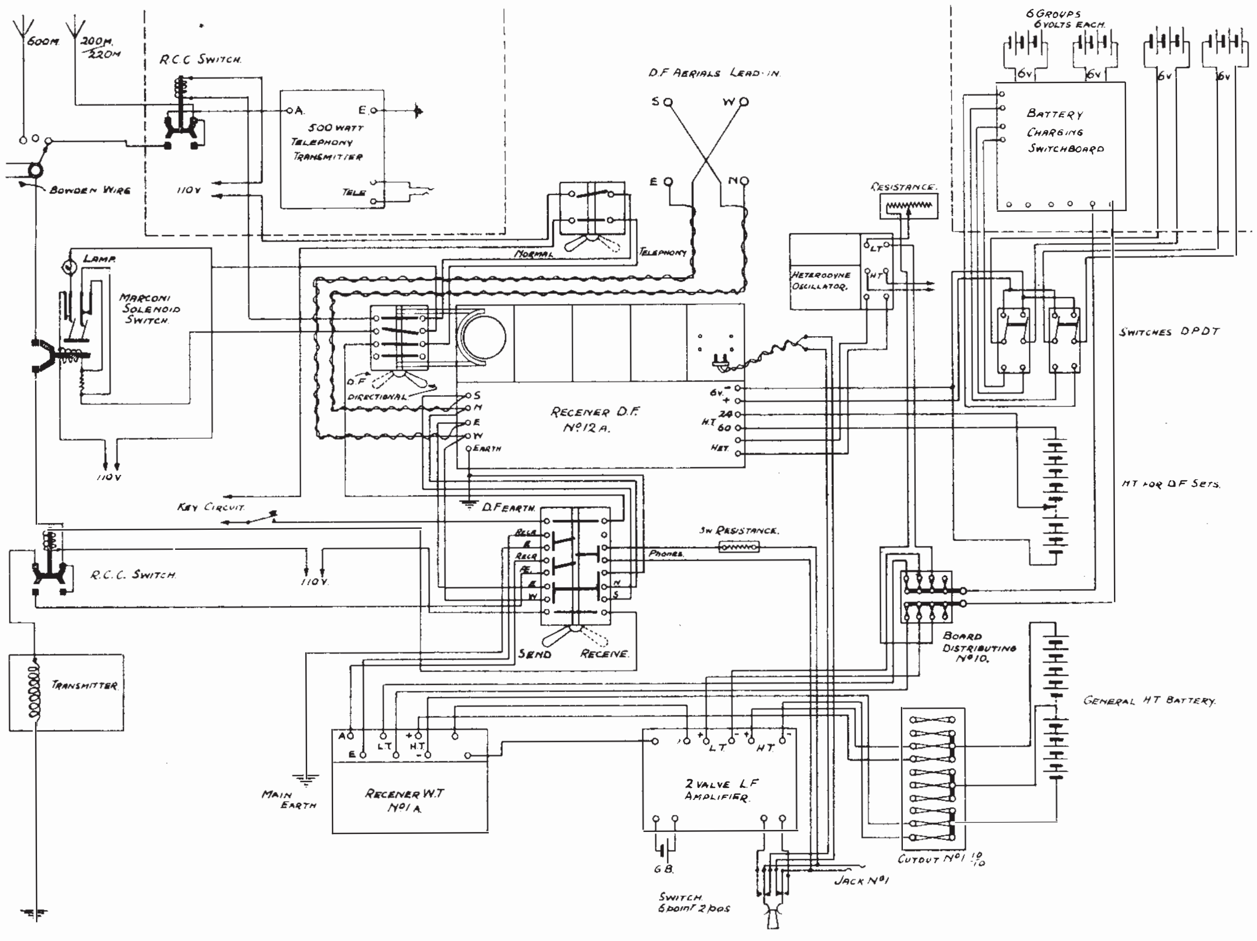


FIG. 9.—DIAGRAM OF CONNECTIONS.

on the main set whilst the telephony set is in operation.

It will be noted that the circuit controlling the R.C.C. switch referred to above is also interlocked with the " Directional—D.F. " Switch so that the action of this latter switch on turning to " D.F." automatically throws the short aerial back to the main set, where it is disconnected by the Marconi Solenoid Switch as already described.

The " Send-Receive " switch when at "Send" performs the usual functions necessary at a D.F. station, in earthing the Bellini-Tosi aerials, disconnecting the Post Office receiver, short-circuiting the telephones and joining up the key circuit, as well as operating a Solenoid switch which transfers the aerial from the receiving to the transmitting apparatus.

Satisfactory tests on C.W. and I.C.W. were carried out with Coast and Ship Stations on completion of the installing work and showed a considerable improvement over the ranges obtained by the old Grimsby Station. Speech ranges of over 200 miles over sea have been satisfactorily effected with the telephony installation.

The Direction Finding plant has been calibrated and was brought into operation on the 19th February last, taking over the D.F. service formerly carried out by the Admiralty Station at Famborough Head, which has now ceased to function.

THE BEHAVIOUR OF A TRANSMISSION LINE AT RADIO FREQUENCIES.

F. E. NANCARROW, A.R.C.Sc., Wh.Ex.,A.M.I.E.E., Member I.R.E.

ALTHOUGH the general case of transmission is well known it does not seem that the solutions have been anywhere developed to portray the behaviour of a transmission line at ultra-radio frequencies where the transmission line is many wave-lengths long. With the development of short wave radio communication such transmission lines are becoming more common and hence the particular development of the general case given below is perhaps not without interest.

The general equations of propagation along transmission lines give rise to the following solutions :—

$$V = Ae^{Px} + Be^{-Px}$$
$$I = Ce^{Px} + De^{-Px}$$

which can be further written (see Appendix I.)

$$V = I_r\,(Z_o \sinh P_x + Z_a \cosh P_x) \quad \text{...........(1)}$$

$$I = \frac{I_r}{Z_o}\,(Z_a \sinh P_x + Z_o \cosh P_x) \quad \text{...........(2)}$$

where V = potential difference at a distance x from the load.
I = current at a distance x from the load.
Z_a = impedance of the load.
Z_o = iterative or surge impedance of the transmission line.
P = transmission constant of the line.
I_r = current at the load.

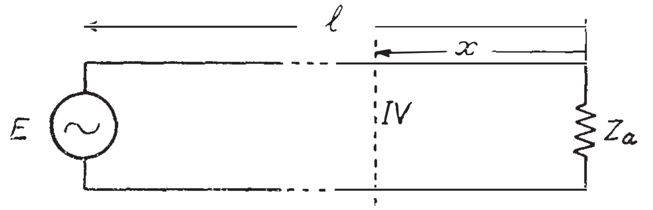


FIG. 1.

By inserting the sending end conditions as shown in Fig. 1, in equation (1), we get

$$E = I_r\,(Z_o \sinh Pl + Z_a \cosh Pl) \quad \text{...........(3)}$$

and substituting the value of I_r so obtained in equations (1) and (2) we have

$$V = \frac{E}{Z_T}\,(Z_o \sinh Px + Z_a \cosh Px) \quad \text{.........(4)}$$

$$I = \frac{E}{Z_TZ_o}\,(Z_a \sinh Px + Z_o \cosh Px) \quad \text{......(5)}$$

where $Z_T = (Z_o \sinh Pl + Z_a \cosh Pl)$; *i.e.*, a constant for a line with fixed terminal conditions.

For frequencies within the telephonic range Z_o is generally a complex quantity and is given by the relation

$$Z_o = \sqrt{\frac{R + j\omega L}{S + j\omega C}} \quad \text{...............................(6)}$$

where R, L, S and C are the resistance, inductance, leakance and capacity respectively, per unit length of line, and $\omega = 2\pi n$, where n equals the frequency of oscillation of the transmitted current.

At radio frequencies, however, R and S are, in general, negligible as compared with ωL and ωC respectively, and hence (6) reduces to

$$Z_o = \sqrt{\frac{L}{C}} \quad \text{.......................................(7)}$$

where Z_o is seen to be a pure resistance.

P, the transmission constant, is given by the relation

$$P = \sqrt{(R + j\omega L)\,(S + j\omega C)} \quad \text{...................(8)}$$

and this can be further written

$$P = \alpha + j\beta \quad \text{...(9)}$$

where α is the attenuation constant of the line and β the so called velocity constant. At radio frequencies it is, in general, impossible to evaluate α except by direct measurement, but β is simply obtained from the relation

$$\beta = \frac{2\pi n}{v} \quad \text{.......................................(10)}$$

where v, the velocity of propagation along the transmission line, is, for ultra-radio frequencies, equal to the velocity of propagation of light.

β can then be alternatively written

$$\beta = \frac{2\pi}{\lambda} \quad \text{...(11)}$$

where λ is the wave-length of the propagated disturbance.

The impedance at any point of the transmission line can be written

$$Z = \frac{V}{I} = Z_o \frac{Z_o \sinh Px + Z_a \cosh Px}{Z_a \sinh Px + Z_o \cosh Px} \quad \ldots\ldots(12)$$

which is independent of sending end conditions.

Converting the sinh and cosh terms into exponentials we get

$$Z = Z_o \frac{(Z_o + Z_a)e^{Px} + (Z_a - Z_o)e^{-Px}}{(Z_o + Z_a)e^{Px} - (Z_a - Z_o)e^{-Px}}$$

$$= Z_o \frac{(Z_o + Z_a)e^{\alpha x}e^{j\beta x} + (Z_a - Z_o)e^{-\alpha x}e^{-j\beta x}}{(Z_o + Z_a)e^{\alpha x}e^{j\beta x} - (Z_a - Z_o)e^{-\alpha x}e^{-j\beta x}}$$

In what follows, α, for the sake of simplicity, will be taken as being negligibly small. If α is not negligible, however, the argument remains unaffected and absolute values are obtained by multiplying the vectors $(Z_o + Z_a)$ by $e^{\alpha x}$ and the vectors $(Z_a - Z_o)$ by $e^{-\alpha x}$.

Assuming $\alpha = 0$, (12) can be written

$$Z = Z_o \frac{(Z_o + Z_a)e^{j\frac{2\pi x}{\lambda}} + (Z_a - Z_o)e^{-j\frac{2\pi x}{\lambda}}}{(Z_o + Z_a)e^{j\frac{2\pi x}{\lambda}} - (Z_a - Z_o)e^{-j\frac{2\pi x}{\lambda}}} \quad \ldots\ldots(13)$$

This equation enables the effective impedance of the line at any point to be readily calculated, and, since the numerater is representative of the voltage and the denominater of the current, these quantities are also readily calculable, due regard being paid to equations (4) and (5).

The numerator of equation 13 is composed of the sum of two unequal vectors rotating in opposite directions with the same velocity whilst the denominater is composed of their difference. Thus four times in every revolution the vectors in both numerater and denominater come into phase, or 180° out of phase with one another, giving a resultant quotient without angle. Hence, whatever the nature of the load Z_a, the transmission line will behave as a pure resistance at points along the line separated by intervals equal to $\frac{\lambda}{4}$, and the value of Z at these points will alternate from the maximum to the minimum values which Z can assume. The first of these points where $Z = Z_R$ (a pure resistance), will be at a distance y from the load where

$$y = \frac{\lambda}{2\pi} \times \frac{\phi}{2} \text{ when } Z_a \text{ is inductive}$$

$$\text{and } y = \frac{\lambda}{2\pi} \times \left(\frac{\pi}{2} - \frac{\phi}{2}\right) \text{ when } Z_a \text{ is capacitative}$$

ϕ being the angle between the vectors $(Z_o + Z_a)$, $(Z_a - Z_o)$ at the load.

Fig. **2**, below, illustrates a case where Z_a is inductive and shows the positions of $Z = Z_R$.

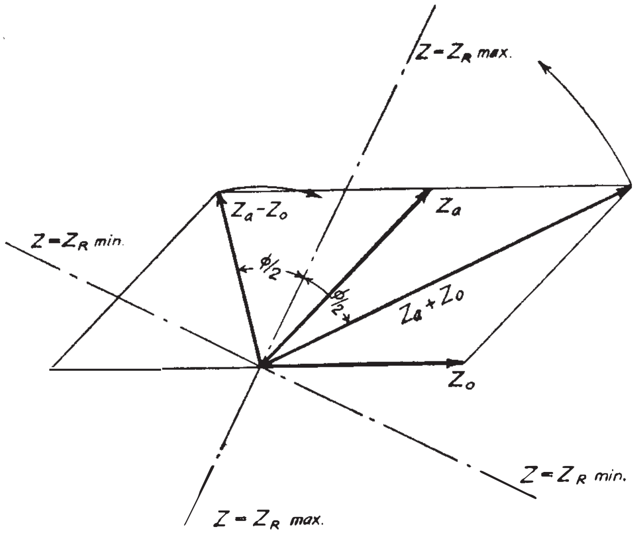


FIG. 2.

Showing the positions where $Z = Z_R$ (*a* resistance) and the phase displacement ϕ at the load of the vectors $(Z_a + Z_o)$, $(Z_a - Z_o)$ for the case where Z_a is inductive.

If the scalar values of the vectors $(Z_o + Z_a)$ and $(Z_a - Z_o)$ be written aZ_o and bZ_o respectively, the maximum and minimum values which Z can assume can be written as follows:—

(*a*) *Maximum value of Z.*

This will occur when the vectors $(Z_o + Z_a)$ and $(Z_a - Z_o)$ are in phase giving

$$Z_R = Z_o \cdot \frac{aZ_o + bZ_o}{aZ_o - bZ_o}$$

$$= Z_o \cdot \frac{a + b}{a - b} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(14)$$

(*b*) *Minimum value of Z.*

This will occur when the vectors $(Z_o + Z_a)$ and $(Z_a - Z_o)$ are 180° out of phase giving

$$Z_R = Z_o \cdot \frac{aZ_o - bZ_o}{aZ_o + bZ_o}$$

$$= Z_o \cdot \frac{a-b}{a+b} \qquad \ldots\ldots (15)$$

From (14) and (15) it is seen that

$$Z_o = \sqrt{Z_R\,(\text{max.})\ Z_R\,(\text{min.})} \qquad \ldots\ldots (16)$$

From equation (13) or Fig. **2** it is clear that midway between the positions Z_R max., and Z_R min., the vectors $(Z_o + Z_a)$, $(Z_a - Z_o)$ are at right angles to one another and thus the resultant vectors in numerater and denominater of 13 are equal to one another in amplitude.

The scalar value of Z for these positions is therefore given by

$$/Z/ = Z_o \frac{\sqrt{(aZ_o)^2 + (bZ_o)^2}}{\sqrt{(aZ_o)^2 + (bZ_o)^2}} = Z_o \qquad \ldots\ldots (17)$$

If Z_{R_1}, Z_{R_2}, Z_{R_3} . . . denote the positions along the line from the load at which Z assumes its resistance values, then a little geometry in connection with equation (13) will show that when the load is inductive Z is inductive in the intervals $(Z_{R_2} - Z_{R_3})$, $(Z_{R_4} - Z_{R_5})$. . . and capacitative in the intervals $(Z_{R_1} - Z_{R_2})$, $(Z_{R_3} - Z_{R_4})$, . . . and *vice versa* for the case of a capacitative load.

The case where $Z_a = Z_o \underline{/45^\circ}$ is portrayed in Fig. **3** below.

From the general case treated above any particular case of loading can be studied. Thus if Z_a be a resistance $= \delta Z_o$ we have

$$a = 1 + \delta$$
$$b = \delta - 1$$

$$\text{and } Z_{R_1} = Z_o \cdot \frac{(1+\delta)+(\delta-1)}{(1+\delta)-(\delta-1)} = Z_o\delta \cdot \qquad \ldots\ldots (18)$$

$$Z_{R_2} = Z_o \cdot \frac{(1+\delta)-(\delta-1)}{(1+\delta)+(\delta-1)} = Z_o \cdot \frac{1}{\delta} \qquad \ldots\ldots (19)$$

also since $\phi = 0$, $y = 0$.

We have therefore the condition that if the transmission line is terminated in a resistance δZ_o, the line behaves as a resistance at points spaced $\frac{\lambda}{4}$ from the load, the value of the resistance at these points alternating from δZ_o to $\frac{1}{\delta}\,Z_o$.

If $\delta < 1$ the line impedance will be inductive between $(Z_{R_1} - Z_{R_2})$, $(Z_{R_3} - Z_{R_4})$ . . . and capacitative in the intervals $(Z_{R_2} - Z_{R_3})$, $(Z_{R_4} - Z_{R_5})$, . . . and *vice versa* if $\delta > 1$.

If $\delta = 1$ the turn $Z_a - Z_o$ in equation (13)—which is the turn taking account of reflection—vanishes, and we have $Z = Z_o$ everywhere along the line.

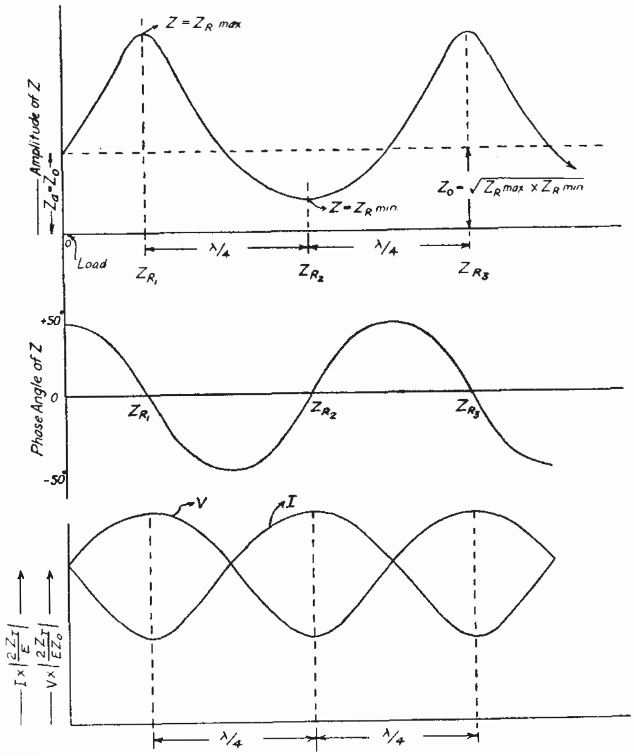


FIG. **3**.

Showing how the amplitudes of Z, V and I and the phase of Z varies with increasing distance from the load. Drawn for the particular case of $Z_a = Z_o\,/45^\circ$.

The current or voltage at any point of the transmission line is dependent upon the total length of line. Thus from equation (5)

$$I = \frac{E}{Z_T Z_o}\,(Z_a \sinh P_x + Z_o \cosh P_x)$$

$$= \frac{E}{2Z_T Z_o}\left[(Z_o + Z_a)e^{j\frac{2\pi x}{\lambda}} - (Z_a - Z_o)e^{-j\frac{2\pi x}{\lambda}}\right] \qquad (20)$$

$$\text{and } V = \frac{E}{2Z_T}\left[(Z_o + Z_a)e^{j\frac{2\pi x}{\lambda}} + (Z_a - Z_o)e^{-j\frac{2\pi x}{\lambda}}\right] \qquad (21)$$

where α has been taken as negligibly small.

At points where $Z=Z_R$ (max.) these reduce to

$$I=\frac{E}{2Z_T}(a-b)$$

$$V=\frac{EZ_o}{2Z_T}(a+b)$$

and where $Z=Z_R$ (min.) to

$$I=\frac{E}{2Z_T}(a+b)$$

$$V=\frac{EZ_o}{2Z_T}(a-b)$$

where a, b, and Z_T have the significance previously stated.

$$Z_T=Z_o \sinh Pl+Z_a \cosh Pl$$

which can be written

$$Z_T=\tfrac{1}{2}\left[(Z_a+Z_o)e^{j\frac{2\pi l}{\lambda}}+(Z_a-Z_o)e^{-j\frac{2\pi l}{\lambda}}\right]$$

if α is assumed very small, and is a function amenable to simple graphical evaluation.

APPENDIX I.

$$V=Ae^{Px}+Be^{-Px} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{I.}$$

$$I=Ce^{Px}+De^{-Px} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{II.}$$

And in any transmission line we have

$$\frac{dV}{dx}=RI+j\omega LI=FI$$

$$\text{and} \frac{dI}{dx}=SV+j\omega CV=GV.$$

$$\text{also } P=\sqrt{FG} \text{ and } Z_o=\sqrt{\frac{F}{G}}.$$

At the load $x=0$ and $V=I_rZ_a$.

Hence putting $x=0$ in equations I. and II. we get

$$\left.\begin{aligned} I_rZ_a&=A+B\\ I_r&=C+D\end{aligned}\right\}$$

differentiating I. and II., substituting for $\frac{dV}{dx}$ and $\frac{dI}{dx}$ putting $x=0$ we get

$$\left.\begin{aligned} \frac{FI_r}{P}&=A-B\\ \frac{GI_rZ_a}{P}&=C-D\end{aligned}\right\}$$

$$\text{Hence } A=\frac{I_r}{2}\left[Z_a+\frac{F}{P}\right]=\frac{I_r}{2}[Z_a+Z_o]$$

$$B=\frac{I_r}{2}\left[Z_a-\frac{F}{P}\right]=\frac{I_r}{2}[Z_a-Z_o]$$

$$C=\frac{I_r}{2}\left[1+\frac{Z_a}{Z_o}\right]=\frac{I_r}{2Z_o}[Z_a+Z_o]$$

$$D=\frac{I_r}{2}\left[1-\frac{Z_a}{Z_o}\right]=\frac{I_r}{2Z_o}[Z_o-Z_a]$$

$$\therefore\ V=\frac{I_r}{2}\left[(Z_a+Z_o)e^{Px}+(Z_a-Z_o)e^{-Px}\right]$$

$$=I_r\left[Z_o \sinh P_x+Z_a \cosh P_x\right]$$

$$\text{and } I=\frac{I_r}{2Z_o}\left[(Z_a+Z_o)e^{Px}+(Z_o-Z_a)e^{-Px}\right]$$

$$=\frac{I_r}{Z_o}\left[Z_o \cosh P_x+Z_a \sinh P_x\right]$$

APPENDIX II.

For a transmission line consisting of two wires raised sufficiently high above the earth, each wire being of diameter d, and the wires being spaced a distance D, it can be shown that

$$L=4\log_e\frac{2D}{d} \text{ per unit length [E.M. units]}$$

$$C=\frac{1}{4\log_e\frac{2D}{d}} \quad ,, \quad ,, \quad ,, \quad \text{[E.S. units].}$$

Hence multiplying L by 10^{-9} to convert to Henrys and C by $\frac{1}{9\times10^{11}}$ to convert to Farads we get

$$Z_o=\sqrt{\frac{L}{C}}=\sqrt{\frac{4\log_e\frac{2D}{d}\times10^{-9}}{\frac{1}{4\log_e\frac{2D}{d}}\times\frac{1}{9\times10^{11}}}}$$

$$=\sqrt{16\log_e^2\frac{2D}{d}\times900}$$

$$=120\log_e\frac{2D}{d}$$

A curve showing values of Z_0 for various ratios of $\frac{2D}{d}$ is given in Fig. **4**.

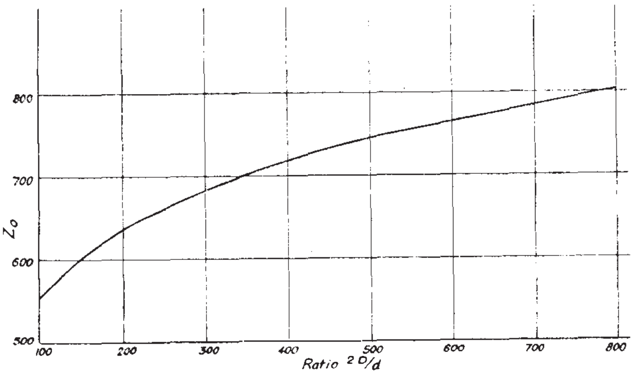


FIG. **4**.

Variation of Z_0 with the ratio $\frac{2D}{d}$ for the case of a raised 2-wire transmission line.

Again for the case of a transmission line consisting of concentric tubes, the inner tube having outer radius r and the outer tube having inner radius R. it can be taken as being approximately correct at high frequencies that

$L = 2\log_e \frac{R}{r}$ and that $C = \frac{1}{2\log_e \frac{R}{r}}$ the values being again in the appropriate units.

$$Z_0 = \sqrt{\frac{L}{C}} = \sqrt{\frac{2\log_e \frac{R}{r} \times 10^{-9}}{\frac{1}{2\log_e \frac{R}{r}} \times \frac{1}{9\times 10^{11}}}}$$

$$= 60\log_e \frac{R}{r}$$

A curve showing values of Z_0 for various values of $\frac{R}{r}$ in the case of this type of Transmission line is given in Fig. **5**.

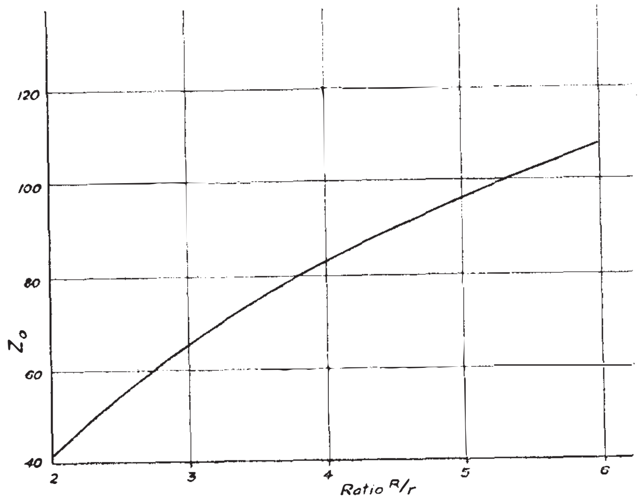


FIG. **5**.

Variation of Z_0 with the ratio $\frac{R}{r}$ for the case of a transmission line made up of concentric tubing.

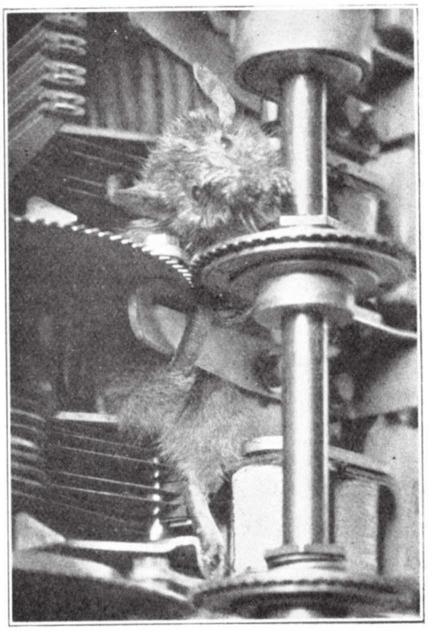
NOTES & COMMENTS

THE Council of Administration of the Association "des Ingénieurs Electriciens sortis de l'Institut Electro-technique Montefiore," Rue Saint Gilles 31, Liége, announces the closing date for their triennial prize competition as the 30th April, 1929. The prize, which amounts to some twenty-nine thousand francs, is awarded to the best work describing a new idea which has had important bearings on developments in the domain of electricity. Further information can be obtained from the General Secretary, M. L. Calmeau, at the above address.

We have received a copy of the Balance Sheet, Revenue Statement and Statistics of the Guernsey States Telephone Department for the year ended 31st December, 1927. The number of exchange lines shows an increase of 176 for the year, the total being now 3,478. The gross revenue is £18758 and the net profit £796, increases of £648 and £34 respectively. It is observed that Trunk service to Alderney opened on the 27th September, a service which, we understand, is superposed on the already existing single core telegraph cable. A similar service to Sark has been in existence since 1915.

We have received the following item and photograph from Mr. A. Jas. Perry, the Shanghai Mutual Telephone Co., Shanghai:—

During a trial run of a Western Electric Rotary System Exchange, recently installed in the Far East, a sudden stoppage caused considerable alarm.



An Automatic rat trap!

A vigorous campaign had been made against deserters of the rat family, who frequent the hotel kitchens next door. Being on the *qui vive*, they were looking for every loophole of escape, and the one shown in the accompanying photograph got into the equipment room through the main cable chute, a casing door having been left off during work. The only damages to the plant were a few gory stains on the shafting and geared drive and a blown fuse.

Going upon this idea, the engineers are now talking about an automatic rat trap!

" *Wired Wireless in Canada.*—The Canadian National Railways Telegraph Department is installing, at a cost of $2,500,000, a new modern high-speed telegraph system between Vancouver and Montreal, which is expected to be in operation within three months. Mr. R. W. Ball, General Manager of the Western region, states that the carrier current system which is being used, and which is practically the application of the wireless audio-frequency system to telegraph service, will make it possible to transmit 84 messages simultaneously. The new system uses two wires, whereas the old sysem used one wire over which eight messages could be sent simultaneously. The new service will therefore result in speeding up communication tenfold. Installation of the new equipment between Montreal and Winnipeg has already been completed.

17, West India Dock Road,
E.14.
3rd May, 1928.

The Editors P.O. *Engineers' Journal.*

Dear Sir,—One misses in our Journal recently correspondence showing that purchasers are reading and weighing the matter in the articles.

I propose to say something about the extract from " Economies in Line Plant Provision."

The teeing system has been tried and found wanting. The fatal objection to it are inherent in the system. If only two D.P.'s are teed, one branch is spare plant when the main cable pair is used; and that spare branch being teed to the working circuit is a menace to it. The teed spare branch adds electrostatic capacity to the circuit and it may—in practice it frequently does—bring low insulation, short-circuits, and earth faults to the working circuit. The more D.P.'s are teed together, the worse the trouble.

The record question is a very serious one. Theoretically possible, it is, in practice, impossible to maintain it as it should be.

When a fault occurs a difficulty arises at once. Imagine the lineman on being handed the fault being told " The circuit is on pair 7 at D.P.243, but it is teed at the junction of Green St. with Romford Rd. with pair 9 on D.P.327." I saw the system in use, saw the trouble and confusion caused, and was glad to see the last of it.

" This will allow one-third of the circuits terminating at a D.P. to be connected direct to the exchange and two-thirds to be teed with other D.P.'s." Taking the above and assuming that the ten year cables reach approximately halfway, then, when the main pairs are all used up, 20% of the total wire mileage, and the most expensive part too, remains spare. But in spite of the teeing it would have been necessary to open joints to put the spares where wanted.

When the main cable pairs are exhausted and a new cable run, then would come the unteeing—and what then?

I think that the auxiliary joint which Mr. Harvey Smith has done so much to popularise is much the best solution yet brought forward. The main pairs are not stumped as stated; they are actually joined up to pairs beyond at the outset, in the best foreseen way; but it is the auxiliary joint only that need be opened when any joint at all must be opened.

The aggregate cost of " wires changed over " is very great. It is a question whether much of the money would not have been better spent in providing new conductors.

Yours faithfully,
E. V. SMART.

HEADQUARTER'S NOTES.

EXCHANGE DEVELOPMENTS.

The following works have been completed :—

Exchange.	Type	No. of Lines.
Armley	New Auto.	590
Tandem (Holborn)	,,	—
Gloucester	,,	1060
Arkwright St.	,,	1000
Churchtown	,,	920
Birkdale	,,	1100
Bishopsgate	,,	7300
Macclesfield	,,	1220
Epsom	Auto Extn.	300
Chapeltown	,,	810
Arkwright st.	,,	500
Sherwood	,,	680
Gosport	,,	270
Portsmouth	,,	—
York	,,	405
Hayling Island	,,	300
Leeds Obsn Desk	,,	—
Ambassador	New Manual	2000
Goole	,,	560
Garston	,,	1400
Northwich	Manual Extns.	180
East (London)	,,	1410
Cambuslang	,,	280
Queens Park	,,	1080
New Cross	,,	900
Weymouth	,,	240
Chiswick	,,	2140
Camberley	,,	260
South Shields	,,	1360
Old Swan (L'pool)	,,	1050
Hecla & Sons	P.A.B.X's	30
Bristol Corporation	,,	50
Blackburn Infirmary	,,	20
Ferranti	,,	Rearrangement.
Groves & Whitnall	,,	30
Harrods	,,	720
Halifax Corporation	,,	50
Hughes & Son	,,	30
Carricks	,,	30

Orders have been placed for the following works :—

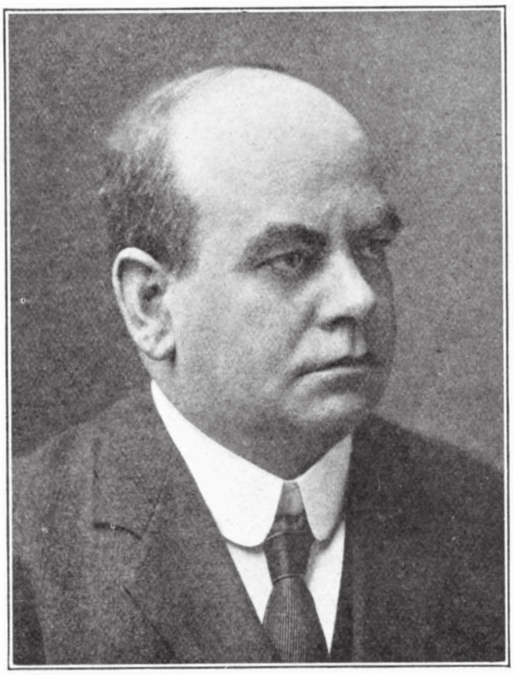
Exchange.	Type.	No. of Lines.
Amherst	New Auto	3600
Fulham	,,	7500
Moss Side	,,	1775
Dudley	,,	1220
Brierly Hill	,,	490
Cradley Heath	,,	540
Stourbridge	,,	1020
Bridlington	,,	1270
Castleton	,,	155
Heywood	,,	365
Littleborough	,,	260
Milnrow	,,	80
Norden	New Auto.	70
Shaw	,,	270
Whitworth	,,	80
Mumbles	,,	570
Fleetwood	Auto Extns.	220
Hayling Island	,,	300
Leeds	,,	Modfns.
Southborne	New Manual	1880
Petersfield	,,	500
Winchester	,,	400
Deal	,,	860
Purley	Manual Extns.	1020
Mansfield	,,	460
Putney	,,	1040
Anfield	,,	1140
Ferranti	P.A.B.X's	Rearrangement.
Delta Metal Co.	,,	20
Davenports	,,	20
Manchester Corpn.	,,	300
Ratcliffe & Ratcliffe	,,	20
Carricks, Ltd.	,,	30
Groves & Whitnall	,,	30
Salford Corpn.	,,	30
Hughes & Son	,,	30
Wiggins Teape & Co.	,,	30
May & Co.	,,	20
Nairn & Co.	,,	30
Calico Printers	,,	30
Atkinson & Son	,,	20

STAFF CHANGES.

Several important changes in the personnel of the higher posts have been recently announced. Mr. Sinnott, who retired on age limit, is succeeded by Mr. E. H. Shaughnessy, whose position as Assistant Engineer-in-Chief will be filled by Lt.-Col. Lee. The Metropolitan Power District has been absorbed by the London Engineering District, and a Deputy Superintending Engineer, in the person of Mr. Gomersall, has been appointed to the L.E.D. Mr. J. W. Atkinson succeeds Mr. T. B. Johnston at Leeds, and Major H. Brown takes Mr. Gomersall's place at Nottingham. Mr. Greenham will go to Croydon on the retirement of Mr. F. Tandy, S.E. of the South Eastern District, and Mr. A. B. Hart will take over the charge of the Lines Section at headquarters when Mr. France retires in November. Mr. Hardham has been appointed Principal Officer in charge of the Staff Section in place of Mr. M. F. G. Boddington, retired on age limit.

We have been fortunate in securing life histories of several of the above. Others will follow in next issue.

MR. J. SINNOTT, O.B.E.



MR. J SINNOTT, O.B.E.

MR. J. SINNOTT, O.B.E., Assistant Engineer-in-Chief, retired from the service at the end of April last, having reached his allotted period but hale and hearty as ever. His popularity with the staff was evidenced by the large gathering which assembled in the Chief's room on the afternoon of the 22nd May to bid him an official farewell and to witness the presentation of a silver tea and coffee service with an engraved salver, which had been subscribed for by members of the staff in all Districts as well as at headquarters. The Engineer-in-Chief presided and opened the proceedings in his usual genial manner. The lead set by the chief was followed by the other speakers, among whom were Mr. Sparkes, Controller of Stores, Mr. De Lattre, Mr. McIlroy, Mr. J. E. Taylor, representing the Districts, Mr. Pollock, Mr. R. A. Wells, Mr. J. W. Atkinson, and Mr. Shaughnessy. All the speeches bore testimony to the ability of Mr. Sinnott, to his characteristic good nature and kindliness of heart and to the valuable services rendered by him to the state.

Col. Purves then made the presentation in a eulogistic but humorous speech, in which he paid tribute to his long friendship with the retiring Assistant Engineer-in-Chief, and to the assistance he had received from him throughout their service.

Mr. Sinnott replied in a similar vein, and excelled himself in the adroitness of his remarks. His explanation of how he grew in weight and in substance while occupying the chair formerly used by Col. Purves caused great amusement. He was leaving them only officially; he trusted he would meet most of the members present on the golf links, where he hoped to be able to reach—if not the plus four position, at least equal terms with another Colonel, namely, Bogey of that ilk. He thanked them all for their kindness and for the good words that the speakers had used towards him.

An account of Mr. Sinnott's career appeared in the July, 1922, issue of the Journal when he was promoted to the position of Assistant Engineer-in-Chief.

LIEUT.-COL. A. G. LEE, O.B.E., M.C., B.Sc., ASSISTANT ENGINEER-IN-CHIEF.

COLONEL LEE'S father was engineer in charge of Bangor section when his son entered the Engineering Department in November, 1901. His first job was with Mr. Tremain, who was then engaged in loading the London-Birmingham cable with experimental air core coils fitted in wooden boxes. The work was extraordinarily interesting and this introduction to the service, plus of course his natural bent in that direction, no doubt led Mr. Lee to devote himself more particularly to the purely scientific side of the work. For several years he was assisting the late Mr. Hartnell in the design and testing of submarine and other types of cables. While engaged in this work he graduated B.Sc. at London University. His articles on

LIEUT.-COL. A. G. LEE, O.B.E., M.C., B.Sc.
[We are indebted to the T. and T. Journal for the loan of this block.]

Telephone Transmission in the early years of this Journal were of the utmost service to the staff and established his reputation as an authority on the subject, which was then beginning to be tackled in a systematic manner by the Administration. In 1908 he was appointed Second Class Engineer at Darlington, and in the following year promoted to be First Class Engineer at Bolton. An open competitive examination for Assistant Staff Engineer in 1912 gave Mr. Lee his opportunity and he came back to headquarters as an Assistant Staff Engineer in the Telephone Section (Transmission and Maintenance Group). He was serving in the Local Lines when war broke out in 1914 and he immediately secured a commission in the R.E. Signal Service. During a large part of the war he was in charge of Telegraph Construction Coy., R.E., and later was O.C., G.H.Q. Signal Area, and at the same time Second in Command, L. Signal Battalion. For his services he received the M.C., and when the war finished he held the rank of Major. He is now Lieut.-Colonel, Royal Corps of Signals (Supplementary Reserve).

On his return to civil life Major Lee was for some time in the Construction Section, but was transferred to the growing Radio Section under the active leadership of Mr. Shaughnessy. In 1921 he acted as British Delegate to the Inter-Allied Radio Conference in Paris and in 1921-2 he visited Egypt and India in connection with the development of wireless services between this country, Egypt and Kurachi. In 1923 he began work on Trans-Atlantic Telephony in conjunction with the A.T. and T. Company. He paid a visit to America in connection with this problem in 1925 and two years later witnessed the culmination of his work in the opening of the telephone service to the States. For his services he was created an Officer of the Order of the British Empire.

Colonel Lee is a Member of the Institution of Radio Engineers and one of the Committee on Admissions to that body. He was chairman of the Wireless Section of the I.E.E. in 1927-8, and was awarded a premium for his opening address to the section. He is a member of several committees of the Radio Research Board and is chairman of the Committee on "Atmospherics."

THOMAS BOYES JOHNSON, M.I.E.E.

Mr. T. B. Johnson, Superintending Engineer of the North Eastern District, retired on the 31st May after completing 43 years' service.

A Yorkshireman by birth, Mr. Johnson joined the Post Office Service at Hull in 1885. Mr. Johnson passed to Newcastle as a Junior Clerk in the P.O. Engineering Department in 1890. His appointment as Engineer in charge of the Newcastle Section came in 1894; subsequently he took charge of the Sunderland Section. At Newcastle the Post Office Telephone system had developed along its own lines under the able guidance of the Superintending Engineer, the late Mr. A. W. Heaviside. It was then competing with the late National Telephone Company. With characteristic energy and resource Mr. Johnson did all that was possible to ensure the satisfactory working of the Trunk and Local (Newcastle) system.

In 1900 the development of the telephone service of London called a number of provincial engineers there on promotion, and Mr. Johnson was promoted to be 1st Class Engineer, and two years later Assistant Staff Engineer. The wide experience gained served in good stead, and he was interested in long distance speech transmission, carrying out experiments between this country and France and Belgium.

In 1907 Mr. Johnson was promoted to be Assistant Superintending Engineer in the Northern District, and for a few years returned to the field of his earlier activities between the Tees and Tweed. It was necessary, however, to make a further break in 1911, on his appointment as Superintending Engineer of the North Eastern District.

The North Eastern District has been fortunate in its association with officers of outstanding personality but never more so than when Mr. Johnson returned to Yorkshire. The first long distance balanced and loaded cable in the country was laid in 1913 between Leeds and Hull. This gave a great impetus to Trunk underground construction generally, and one of the first to grasp its significance was Mr. Johnson, who never ceased his advocacy of the extension of underground; nearly all the towns in the District are now linked up by underground cables. Concurrently, a large extension of local underground was carried out. In 1918 the Leeds Automatic Exchange was brought into service. This is considered to be a turning point in Telephone history in this country, inasmuch as no large industrial city had been worked on the Automatic System. The success at Leeds Exchange assisted the case for the general adoption of Automatic working. Mr. Johnson was not content to support the extension of Automatic working by recommendation only, but gave lectures and demonstrations. Since the Leeds Exchange was opened, Automatic working has been introduced at Grimsby, York, Harrogate, Halifax, Wakefield, Sandal, Keighley, and five Satellite Exchanges in the Leeds Automatic Area.

Outside the Department Mr. Johnson's activities have been varied and heavy. He has been Chairman of the North Midland Centre of the Institution of Electrical Engineers. His address as Chairman was a noteworthy definition of his broad outlook on modern industrial conditions. For many years, too, he has taken an active part in Church work, not only locally, but in the Ripon Diocese.

Mr. Johnson's relations with his staff have been cordial. Even during the war period when

Mr. T. B. Johnson.

so many changes were made and in the reconstruction period after the war, the staff problems were disposed of with surprising smoothness. He was always ready to help in any way possible. Naturally a very kindly chief, he was most anxious to alleviate cases of hardship or misfortune which came to his notice.

The Staff of the North Eastern District presented Mr. Johnson with a five-valve portable wireless set, and Mrs. Johnson with a handbag, on the occasion of a complimentary dinner at Leeds. Mr. A. L. De Lattre, Assistant Engineer-in-Chief, was present, together with old friends and colleagues—Mr. J. D. Taylor, Superintending Engineer, Edinburgh; Messrs. Bailey and Whillis, of the Engineer-in-Chief's Office; Mr. Bell Smith, Postmaster of Bradford, representing the Postmasters, and Mr. T. A. Bates, District Manager. Mr. G. S. Wallace, Assistant Superintending Engineer, occupied the chair, and Mr. W. S. Tinsley, Sectional Engineer, Bradford, proposed the health of the guest. Mr. S. A. Pickering, Staff Officer, made the presentation.

It is a matter of deep regret to Mr. Johnson, and the Staff in the North Eastern District, that Mr. F. E. Gibbins, late Assistant Superintending Engineer, had to retire from active work in April owing to ill-health.

It is difficult to couple Mr. Johnson's name with leisure in view of his present activities. He leaves the Service with the best wishes of the

Staff for his continued happiness. If, at any time, he is persuaded to take some leisure, some say that the hills and moors beyond the Wharfe will still test his powers as a pedestrian. On the other hand, there is undoubtedly a call from the east where walking is not so strenuous, where the country is close to the river and the sea, not far from the City of the Three Crowns—Holderness.

How heavy do I journey on the way
When what I seek, my weary travels end
Doth teach that ease and that repose to say
"Thus far the miles are measured from thy friend."

MR. E. GOMERSALL.

Mr. E. Gomersall.

Mr. E. Gomersall, O.B.E., M.I.E.E., who took up duty as Deputy Superintending Engineer in the London District on the 1st June, entered the Engineering Department at Leeds in 1895. He was transferred to the Engineer-in-Chief's Office in London in 1898 and was associated for many years with the Assistant Engineer-in-Chief, the late Mr. M. F. Roberts, who was responsible for the design and method of the underground construction adopted in connection with the scheme for the telephoning of London. On 1/7/00 he was promoted to Engineer 2nd class, and on 1/9/04 after a competitive examination to Technical Officer 2nd class. During the following years he was attached to the Headquarters Staff and was engaged chiefly on external construction matters until 1909, when he was transferred to the South Metropolitan District as Assistant Superintending Engineer. In this District he assisted in dividing the Southern District after the transfer of the Royal Engineers to Ireland, and in the formation of what is now the South Eastern District.

During the greater portion of 1912 he was Acting Superintending Engineer of the South Metropolitan District, during which period the Engineering Staff and plant of the National Telephone Company were merged in that District. It is interesting to note that during the period Mr. Gomersall was in charge of this District the automatic equipment at Epsom was opened—the first automatic exchange in Great Britain. Automatic Exchange transfers have also engaged his attention for the last two years, during which period 23 Automatic Exchanges were brought into use in the North Midland District, including Chesterfield, Sheffield, Coventry, Nottingham and Leicester. The simultaneous transfer at Sheffield from Magneto to Automatic working was the largest operation of the kind undertaken by the Post Office up to date. Eleven Magneto Exchanges were closed and 9 new Automatic Exchanges were opened.

On the formation in 1912 of a new London Engineering District, Mr. Gomersall was transferred to Reading as Assistant Superintending Engineer, where he was associated with Mr. McL. Robb in forming the new South Midland District, incorporating part of three other Districts and combining the National Telephone Company and the Post Office staffs in the territory.

At the outbreak of war, Mr. Gomersall was actively engaged in various defence and other schemes in the military areas in the South Midland District.

On the 23rd April, 1915, he took up duty as Superintending Engineer in Ireland in replacement of the Royal Engineer Officer who had been withdrawn. He had to face many difficult problems in Ireland. The Post Office staff maintained practically all the Railway signalling lines and apparatus, as well as the telephone and telegraph system and a number of important wireless stations, including Valentia and Malin Head.

In Easter, 1916, came the Irish Rebellion, and with it the destruction of the General Post Office in Dublin and the line plant there and in different parts of the country. In the trying times which followed, Mr. Gomersall was in close touch with the Admiral commanding at Queenstown, the Irish Command at Dublin and the United States Air Force Command, and many large and important schemes of communication, open, underground and submarine, were carried out successfully.

In recognition of his work at this time, Mr. Gomersall was awarded the decoration of Officer of the Order of the British Empire.

In July, 1919, Mr. Gomersall was transferred to England as Superintending Engineer of the North Midland District and during the nine years which followed considerable development took place in that District. The number of telephone stations increased by 110%, the mileage of underground wire by 303%, the mileage of duct by 209%, the mileage of open wire by 30% and the number of Exchanges by 38%.

634 miles of main underground cable were laid including the London-Manchester, London-Derby and Derby-Leeds main cables. The Leicester Repeater was opened and subsequently the Derby Repeater Station.

Recently, Mr. Gomersall has devoted much time to the application of machinery to the Department's accounting requirements and to the simplification of the Unit Construction Cost system. He takes with him to his new sphere the good wishes of the staffs of the various Districts in which he has worked.

MR. G. F. GREENHAM.

Mr. G. F. Greenham.

Mr. Greenham was educated at Emmanuel School, Wandsworth Common, at King's College (London University) and for one year at a school in Germany.

At King's College he studied under the late Dr. John Hopkinson and Prof. Ernest Wilson, and gained a scholarship which entitled him to a further period of one year in the Siemens Electrical Laboratory, free on the understanding that he assisted in the conduct of the evening classes.

During this period he was associated with Dr. Hopkinson's research work on the distribution of magnetism in iron, concerning which a paper was read before the Royal Society.

After leaving King's College he spent a year as an improver in the Charing Cross and Strand Electricity Supply Station. This station was at the time equipped with Williams' high speed engines and Mather and Platt dynamos.

In March, 1895, a friend suggested to him that the telephone business offered a good field for young engineers, and Mr. Greenham joined the National Telephone Company's service as switchboard fitter. The change from lighting station switchboards to telephone switchboards was very marked.

His first employment was at the exchange in Queen Victoria Street. A new switchboard of the flat multiple type was being built to replace the single line switchboard then in operation.

The flat board gave good service, being recovered in June, 1926, after 31 years' service. For many years it was known as the Bank Exchange. When the new switchboard was put into service Mr. Greenham became Test Clerk and, later, exchange inspector.

In 1897 he was transferred to the Gerrard Exchange. While there the flat board was replaced by one of the Christiania type. This installation was not a success and the Christiania board was subsequently replaced by a C.B. board. In June, 1899, he was appointed Switchroom Manager. The Switchroom Manager in those days controlled the electrical work, both construction and maintenance as well as the traffic.

In 1901 Mr. Greenham became Assistant Electrician, Western District (London). In this capacity he took part in the provision of the first C.B. exchange in London (Kensington). In 1903 he was appointed Electrician of the Western District, under the then District Manager—Mr. R. A. Dalzell. In 1905 the staff of the Metropolitan Area was re-organised on functional lines under Mr. C. B. Clay, the Superintendent at this stage, and Mr. Greenham became Metropolitan Maintenance Electrician and in 1907 Metropolitan Electrician responsible for all internal construction and maintenance. During his period of service with the Company he was connected with two big events—the London Wall exchange and Bank Test Room fires.

Mr. Greenham was one of three men who started and ran the Company's Correspondence Classes. In 1911 he was transferred to the P.O. Engineering Department as Assistant Superintending Engineer, Met. South District. Shortly afterwards the present London Engineering District was formed under the Superintending Engineership of Mr. A. Moir, when he was transferred to Denman Street.

During the war period he acted as liaison officer between the Department and the London Air Defence Control and was responsible for the equipment, so far as communications were concerned, of the gun and searchlight stations and control stations, including the arrangements at G.H.Q. Horse Guards. For his services he was made M.B.E. In 1922 he was elected to fill the vacancy for an Assistant Staff Engineer caused by the transfer of Mr. H. P. Brown to Australia.

Since his advent in the Engineer-in-Chief's Office the amount and complexity of the duties have grown considerably, thanks to the activities in connection with the introduction of the automatic system, particularly the Director System. As a measure of his responsibilities it may perhaps be pointed out that he was responsible to the Staff Engineer for the work of five groups performing widely different duties.

MAJOR H. BROWN.

Mr. Brown entered the Superintending Engineer's Office at Birmingham in 1896, after serving six years in the Telegraph Instrument room in that city. In 1900 he was appointed Sub-Engineer at Coventry and in 1903 he became Second Class Engineer in charge of the Stafford Section. In spite of a small staff, many big works were carried out in the section and on the reorganisation in 1904 he was transferred to the newly formed District Estimates Section, from which he was transferred by Major O'Meara, then Engineer-in-Chief, to the Survey (now Lines) Section at headquarters. In 1910 Mr. Brown was promoted to be First Class Engineer at Belfast and while there he was sent as one of the Department's representatives to the International Telegraph and Telephone Conference at Paris. Later in the same year he was seconded for duty on the Inventory Staff for the valuation of the N.T. Coy's plant. On completion he returned to headquarters in charge of a valuation group, and during the time the case was before the Courts he and the late Mr. Walter Twells were engaged until well after midnight on many nights preparing for the next day's proceedings. For his services he received a special award of £200 from the Department.

Mr. Brown was in the Local Lines when he was appointed Assistant Director of Army Signals, with the rank of Captain, prior to the war, and on the outbreak he acted as assistant to the late Sir Andrew Ogilvie. He was then given

Major H. Brown.

command of No. 5 Telegraph Construction Coy. in France. He was twice mentioned in Despatches and awarded the O.B.E.

Since his return he has been engaged in the Construction Section, chiefly on the delicate work of negotiation with Road authorities in respect of costs of re-instatement of pavings and damage to property. In June last year Major Brown was sent on a commission to Sweden to inquire into the methods of construction adopted in that country, and what he saw there he has detailed to many hundreds of his colleagues during the tour he has made throughout the country to effect economies in construction costs.

At the last grand manœuvres in the South West of England, Major Brown was the P.O. representative at the Directing Force camp, and he has acted in other matters for several years past as a liaison officer between the Department and the Defence forces of the country.

LONDON DISTRICT NOTES.

Telephones.—The changes in the number of exchange lines, extensions and stations during the quarter ending, and the totals on, 31st March, 1928, were as follows :—

	Increase.	Total.
Exchange Lines ...	8,570	335,502
Extensions ...	4,365	280,832
Stations	11,8832	561,744

External Plant.—The changes in mileage during the three months ended 31st March, 1928, and the totals on that date were as follows :—

Line Mileage.

	Increase Miles.	Total Miles.
Pole Line	31	5,855
Pipe Line	187	9,625

Single Wire Mileage (decreases in italics).

	Overhead. Miles.	Underground. Miles.	Total. Miles.
Telegraphs ...	*4*	238	25,218
Telephones (Ex.) ...	*537*	42,057	2,235,536
,, (Trunk).	*54*	2,720	71,281
Spare*	—	—	106,950

Exchange Works.

The installation of the Automatic Exchanges known as Sloane, Bermondsey and Monument is well advanced and it is expected that they will be opened, in the order named, during the next few months.

Fairfield Exchange—hypothetical on Croydon—was opened on May 2nd.

Ingrebourne Exchange (C.B.S.), situated in the Sunny Town Post Office, has been installed to relieve the Romford Exchange and was opened on May 24th.

Temple Bar (Relief) Exchange was opened on May 25th on the old Holborn manual equipment and forms a nucleus for transfer to Temple Bar (Auto.) Exchange at a later date.

Beckenham (Relief) Exchange—C.B. No. 10, capacity 800 lines, is being installed by the Department's staff, and, it is anticipated, will be opened for traffic on July 14th.

The General Electric Company have started work on the new Sutton Exchange. The equipment (C.B. No. 1) will provide for 4,880 lines.

At Woolwich Exchange an extension of 1,080 lines was commenced by Messrs. Siemens on May 21st.

Willesden Exchange equipment is being increased by 1,060 lines to a total capacity of 7,400 lines. It is anticipated that the work, which is

* *i.e., excluding small gauge local conductors.*

being carried out by the General Electric Company, will be completed by September.

Included in the P.B.X. installations now in hand are two C.B. 10A equipments for Imperial Chemical Industries Limited and Grosvenor House, respectively, each of which has a capacity of over 1,000 circuits. A P.A.B.X. has recently been installed by Messrs. Siemens for Messrs. Harrods, with a capacity for 900 extensions. This was brought into service at the end of May.

The transfer of Lloyds from the Royal Exchange to the new building in Leadenhall Street, which was officially opened by the King on 30/3/28, involved the installation of the following:—

Lloyds Exchange Service—

2 Switchboards $\frac{10 \times 50}{65}$
12 Exchange lines.
81 Internal extensions.
3 Tie lines.

Underwriters' Installations—

3 Switchboards No. 9.
8 Incoming Exchange lines.
18 Outgoing Exchange lines.
5 Bothway Exchange lines.
26 Lines to cabinets.
90 Extension lines to Underwriters' tables in main hall.
90 Private wires to Brokers' Offices.

Main Frame—

1000 Pair cable to Avenue Exchange.
200 Pair cable to Central Exchange.
1400 Pairs to various floors.
1200 Miscellaneous circuits.

MACHINE TELEGRAPH SCHOOL.

A small school has been fitted up with Start-Stop apparatus to enable instruction to be given to operators. This school is on similar lines to that provided for the engineering staff.

TELEGRAPHS.

Central Telegraph Office.

New Test Room.—The first stage of the new Test Room has been completed, namely, the erection of the ironwork with accommodation for 10,000 wires. It occupies a large room in the basement of the main building; whereas the existing frame is outhoused in an unsatisfactory position in the area.

Telegraph Typewriters. — These have now become engineering items. At the C.T.O. 134 typewriters have either been newly provided or taken over from the Stationery Office, and are to be maintained by engineering workmen. They have been supplemented by double-slip guides and lecterns; covers have also been fitted over the keyboards of instruction machines, to force students to rely on touch alone.

Slip-Wheels.—The needs of the Beam Services have led to a proposal for slip-wheels with springs at the sides, so that the relative telegram forms may be associated with the perforated slips.

Baudots. — The conversation to automatic working continues, the latest circuit altered being Newcastle.

Pneumatic Tubes.—Building operations at the C.T.O. having revealed unsatisfactory supports of the tubes, the facilities afforded by the Office of Works scaffolding enabled new supports to be provided, and, incidentally, to improve the general appearance of the ceiling above the Centre.

An engineering officer has devised new types of Carriers constructed of rubber. Another officer has devised a new type of teleswitch for use on automatic tubes.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS.

THE Annual General Meeting of the Institution was held at the Institution of Electrical Engineers London, on Tuesday, May 8th, 1928. The Chair was taken by the President, Col. T. F. Purves, M.I.E.E.

The Annual Report of the Council was read by the Secretary (Dr. R. V. Hansford) and the Annual Financial Statement was presented by the Treasurer (Mr. B. O. Anson). Mr. J. W. Atkinson moved the adoption of the Annual Report and Financial Statement and this was seconded by Capt. J. G. Hines. After Mr. Anson had replied to several queries raised by the speakers the resolution was carried unanimously. Mr. S. Upton proposed a hearty vote of thanks to the retiring Members of the Council, Messrs. A. S. Carr, C. W. Messenger, H. J. Millett and E. J. Wilby, for their services on behalf of the Institute. This was seconded by Mr. J. Cowie, and Mr. A. S. Carr replied on behalf of he retiring members.

The President then presented the Institution Medals for the Session 1926-27 as follows:—

Senior Silver Medal to Mr. J. Innes, B.Sc., for Paper No. 114 on "The Edinburgh Automatic Multi-Office Transfer."

Senior Bronze Medal to Mr. W. Cruickshank, M.I.E.E., for Paper No. 113 on "Voice Frequency Telegraphs."

Junior Silver Medal to Mr. B. Miller, for Paper No. 115 on "Wayleaves and Relative Difficulties."

The President also presented Mr. R. W. O. Abbott, Cable Room Workshop, C.T.O., with the Booth-Baudot Award for the year 1927-8 for his suggested improvements in telegraph systems.

The Annual Meeting was followed by a meeting of the London Centre, at which an address was given by Capt. B. S. Cohen, M.I.E.E., on "The International Committee on Long Distance Telephony and some aspects of its Engineering Work," of which the following is a synopsis:—

Introduction and historical.
Note on the growth of International Telephony.
Organisation of the Committee.
The five sub-committees dealing with engineering subjects.
Transmission units.
Overall transmission allowance from subscriber to subscriber on International Circuits, and allocation of the allowances between the instruments and the circuits.
Telephone Transmission Master Reference System, and general notes on its construction, installation, calibration and operation.
Transmitter and receiver, electro-acoustic efficiencies.
Articulation and intelligibility; how defined and measured.
Some articulation efficiencies of transmitters, receivers, lines, etc.
The testing of the transmission efficiency of subscribers' instruments *in situ.*
Notes on telephone acoustics with a brief introduction to the theory of plane and spherical fields of sound radiation and electrical analogies.

COUNCIL FOR THE YEAR 1928-29.

The constitution of the new Council is as follows:—

Chairman—Mr. A. L. DeLattre.
Honorary Treasurer—Mr. C. J. Mercer.
Representing Staff of the Engineer-in-Chief's Office—
Mr. B. O. Anson and Mr. P. J. Ridd.
,, Executive Engineers—
London: Mr. J. Cowie.
Provinces: Mr. S. Upton.
,, Asst. & Second Class Engineers—
London: Mr. P. G. Hay.
Provinces: Mr. A. E. White.
,, Chief Inspectors—
London: Mr. J. D. Boulton.
Provinces: Mr. W. A. Satchwell.
,, Clerical Staff—
London: Mr. E. T. Larner.
Provinces: Mr. H. Longley and Mr. H. Willcock.
,, Inspectors—
London: Mr. N. Layton.
Provinces: Mr. Thos. Davidson.
,, Draughtsmen—
London and Provinces: Mr. R. J. Stewart.
Secretary—Dr. R. V. Hansford.

PRINTED PAPERS.

The following is a list of the printed papers issued to the Membership during the year 1927-28:—

No. 108. "Some Applications of Optical Methods to the Examination of Engineering Material," F. O. Barralet, M.Inst.Metals, A.M.I.E.E.
No. 109. "The Problem of Flexibility in Subscribers' Cable Distribution," Harvey Smith.
No. 111. "Scientific Organisation and the P.O. Engineering Department," F. G. C. Baldwin, M.I.E.E.

No. 112. "Telephone Repeaters and their Maintenance," C. Robinson, B.A., A.M.I.E.E.

No. 113. "Voice Frequency Telegraphs," W. Cruickshank, M.I.E.E.

No. 114. "The Edinburgh Automatic Multi-Office Transfer," J. Innes, B.Sc.

No. 115. "Wayleaves and relative difficulties," B. Miller.

The following paper is in the press:—

No. 110. "Testing of Telephone Circuits and Apparatus with Alternating Currents," E. S. Ritter, D.F.H., A.M.I.E.E., and G. P. Milton.

The Council has decided to print the following papers:—

"The Director. Its Application and the Functions performed," C. W. Brown, A.M.I.E.E.

"Satellite Working in Automatic Areas," F. I. Ray, B.Sc., F.H.D., A.M.I.E.E.

"Sparking and Arcing at Relay Contacts and the use of Spark Quench Circuits," A. H. Jacquest, A.M.I.E.E., and L. H. Harris, M.Sc.(Lond.), A.C.G.I.

LOCAL CENTRE NOTES.

SCOTLAND EAST CENTRE.

The opening meeting of the Session was held in the Royal Scottish Society of Arts Hall, Edinburgh, on November 24th. The Chairman, Mr. J. D. Taylor, intimated the sudden and unexpected death of Mr. J. C. Sim, Draughtsman, and members stood in silence as a mark of respect and esteem. After a few appropriate remarks, the Chairman introduced the lecturer, Mr. F. I. Ray, B.Sc., D.F.H., A.M.I.E.E., of the Engineer-in-Chef's Office, who lectured on "Satellite Working in Automatic Areas." The lecture proved most interesting and instructive, and was illustrated by a splendid series of lantern slides. Full working models showing various arrangements were operated during the course of the lecture, and afforded an exceedingly useful demonstration. Mr. J. Innes and Mr. J. S. Elston raised a number of interesting points which were replied to by Mr. Ray.

At the December meeting Mr. R. T. Robinson, A.M.I.E.E., Engineer-in-Chief's Office, lectured on "Motor Transport in the Engineering Department." After dealing with its historical aspect and describing the various makes of vehicles in use, the Lecturer's headings included Statistical records, Estimated savings and Percentage efficient use, Inspection reports, Overhauls and Repairs, Replacements, Trading account, Future development, and Training of Staff. Lantern slides were used to illustrate the various points as the lecture proceeded. The subject provoked a very long, keen and interesting discussion, which showed how closely this phase of the Department's operations was being studied.

The arrangement under which the Stores Department deals with the Engineering work in connection with postal motor vehicles was severely criticised by several speakers. The work could, without a doubt, be handed over to the Engineering Department with marked advantage to the Service.

At the third meeting of the Session on 17th January, Mr. J. McIntosh read a paper entitled "Forms and Methods in Preparing Estimates." He proceeded to show how, by the use of suitable forms, the work of preparing estimates, including the pricing of the stores in blocks, could be considerably simplified and expedited, and the risk of omissions reduced to a minimum. The system provided the Works Inspector with a detailed plan of the work to be undertaken and a ready means of keeping in touch with the work as it progressed and noting at once any necessary departures and the reasons for them. It also provided for the efficient clerical control of Stores. Other suggestions included an ingenious set square with standard symbols, also an arrangement for determining the available spare space in ducts and pipes; and a simplified method of preparing local line plant records.

A useful item included in the suggestions was a slide rule, which had been made by Mr. McIntosh, together with instructions regarding its use. The slide rule enables the diameter, make-up, etc., of Lead Covered Paper Core Composite Cables to be calculated in a mere fraction of the time ordinarily taken, and also provides a ready means of ascertaining the weights of recovered scrap lead and copper for estimate purposes. The discussion was of a very high order and was ably replied to by the lecturer. Many of the suggestions have been tried out in actual practice, with entirely satisfactory results.

The system is simple and effective as compared with existing procedure, and the bulkiness of the numerous tables, etc., which had been prepared, serves but to emphasise the gigantic tasks which form the day to day routine of the Engineering Department.

The February meeting took the form of a joint session with the Institution of Electrical Engineers, Scottish Centre, and was open to the general public.

An illustrated lecture, entitled " Rugby Radio Station," was delivered by Mr. E. H. Shaughnessy, O.B.E., M.I.E.E., M.I.R.E., Assistant Engineer-in-Chief. As the lecturer proceeded to develop his subject in an easy conversational style, the crowded gathering followed each phase with wrapt attention, and it was readily apparent that the subject matter made a strong appeal to all who were privileged to be present.

Sir J. Alfred Ewing, K.C.B., M.A., D.Sc., L.L.D., F.R.S., Principal of the Edinburgh University, presided at the meeting and also moved a vote of thanks to the lecturer. The choice of chairman was particularly appropriate, as the lecturer was in close association with him on important work during the war. The lecture was given considerable publicity. Display bills were posted throughout the town, the newspapers printed preliminary reports, and a detailed announcement was broadcasted on two occasions. The various Scientific Societies and Educational Bodies were well represented at the meeting, and more than 1,500 requests were received for the 750 available tickets. The freely expressed opinion was that the lecture had been an unqualified success, and it was certainly an excellent advertisement of the Post Office activities.

At the meeting on 20th March, the chairman intimated that the Senior Silver Medal of the Insitution had been awarded by the Council to Mr. J. Innes, B.Sc., for his paper entitled " Edinburgh Automatic Multi-Office Transfer." Mr. Taylor, on behalf of the members, congratulated Mr. Innes and said that the award of the Medal was very gratifying to his fellow members in the Scotland East Centre.

Mr. H. Burgher then read a paper on " Problems and Methods of Subscribers' Distribution." Edinburgh is probably unique as regards the large number of lofty tenements, each house of which is generally owned by a different landlord. The lecturer dealt with the ex-National Telephone Company's system of distribution by means of roof standards, and showed the advantages gained by scrapping that system. Smaller D.P. areas and block-wiring schemes had provided a more economical and reliable service, and reduced to a minimum the dangerous overhead maintenance work.

The organisation for carrying out block-wiring schemes was detailed. It was considered that a lay-out plan of the work should be prepared a few hours in advance of the work being actually put in hand. Particulars were given of a specially made tool for dooking walls, which had given excellent results. The desirability of including in the gang a first-class jointer skilled in all departments of cable jointing was emphasised. A new form of cable clip was suggested, which, it was claimed, would avoid the necessity for " threading " cables, with the consequent liability to damage to the lead sheathing, and would also provide a quicker and more economical arrangement for replacing cables.

The advantages accruing from the fixing of C.D. Plugs upside down, together with an improved method of fixing the plug and tails to the wall, were explained. A suggestion was made that telephone wires should be led in at the top of windows and builders of future houses should fit a suitable pipe between the top of the side frame of the window and the lintel, where it would be in a sheltered and protected position. The paper was followed by a useful discussion.

The Agenda then provided for " Informal Discussions."

The subjects dealt with included " Fault Returns," " The Right Mental Attitude towards Subscribers' Complaints," " A Working week of five days for Gangs in Isolated Localities," " Standard Form used in connection with the Provision of Subscribers' Circuits," " Improvements which could be effected by the Control of Complaints directly in Automatic Exchanges at the Test Desk instead of by the Monitors as at present." The subjects were fully debated.

Hearty votes of thanks to all the Lecturers were carried with acclamation.

SOUTH LANCASHIRE CENTRE.

At the sixth meeting of the Session, held on March 5th, Mr. A. S. Renshaw, of the Engineer-in-Chief's office, gave an informal address on "Some Considerations relating to the Clerical Organisation of the Engineering Department." A very interesting review was given of the improvement which have been made in the clerical organisation during the past 15 or 20 years, followed by an explanation of the basis on which the size of the clerical staff was at present determined. Criticism of these arrangements was sought from the members, and a spirited discussion resulted.

At the final meeting, held on April 2nd, a joint paper was presented by Messrs. F. E. Bentley, A.M.I.E.E., and L. H. Crane, A.M.I.E.E., entitled "Underground Cable Maintenance — Notes on the results of three years special testing." The paper, while referring to the success achieved by Routine and Precision testing, dealt more particularly with the large number of electrolytic corrosion cases experienced in the District. A description was given of the systematic surveys of sheath currents and voltages which had to be undertaken and the manner in which the source of such currents was traced. A useful discussion followed.

NORTHERN CENTRE.

On the 18th January Mr. G. F. Bellwood, M.I.E.E., delivered a paper on "Through Signalling on Trunk and Junction Circuits." The author stated that the object of the paper was to deal in a simple manner with through signalling over circuits worked on a full automatic signalling basis. The facilities provided by such circuits were detailed. The arrangements for through signalling on C.B.S. No. 1 Exchange circuits and on circuits connecting different types of Exchanges were described, together with the apparatus connections involved in setting up such calls by controlling telephonists. The through clearing operations from the distant subscribers to the Controlling Exchange were also described and notes given on the difference between the method of through signalling in C.B.S. No. 1 Exchanges compared with Common Battery and C.B.S. No. 2 Exchanges. The paper was illustrated with diagrams and was commented upon as being instructive and interesting.

On the 15th February Mr. W. Weightman read a paper on "The Laying of Holy Island Cable." The work in question was the laying of a four core light sheathed Submarine Cable across, approximately, three miles of mud flats between Beal and Holy Island T.P's. and followed on a decision to provide a Call Office at Holy Island Post Office and to provide additional communication facilities for the Coast Guard Station. The author described the organisation for carrying out the work and the method of laying the cable which was adopted, together with the reasons for its adoption, and the alternative methods which were available. The difficulties encountered in carrying out the work were dealt with and the varying experiences of the men, who, owing to the lack of housing accommodation on the Island, were provided with a well-organised camp, replete with all conveniences for their comfort, were described.

The paper, which was rather out of the ordinary, was illustrated with twenty-two slides and was very well received.

The Junior Silver Medal has been awarded by the Council to Mr. B. Miller for his paper on "Wayleaves and their Difficulties."

Arrangements are in hand for a summer outing in the second week of July.

NORTH WALES CENTRE.

The final meeting of the 1927-28 Session was held at Shrewsbury on 14th March, 1928, when Mr. E. A. Pearson, A.M.I.E.E., read a paper entitled "Waste," of which the following were the principal headings :—The need for economy; Engineering design in relation to waste; The function of an Engineer; Capital Expenditure; Lost interest and lost revenue; Temporary work; Plant Lay-out; Standardisation; Planning Department; Execution of works; Misdirected Energy; Waste of time, — Prevention and checks; Importance of the individual. The paper was a very thoughtful and comprehensive contribution and provoked a lengthy discussion and many appreciative comments.

BOOK REVEIWS.

Official Minutes of the work of the 4th Plenary Conference of the International Advisory Committee on Long Distance Telephony (C.C.I.) held at Como from 5-12 September, 1927.

1. List of delegates and experts from the private industry.
2. Minutes of the Opening Session.
3. Questions of General Organisation.
4. Questions of transmission, maintenance and supervision on lines and in exchanges.
5. Questions of traffic and operating.
6. Questions concerning the protection of telephone cables against electrolytic action and chemical action.
7. Minutes of the Closing Session.
8. Summary of questions dealt with by the Committee since its inception.

Book in quarto paper cover, containing 169 pages and 37 illustrations. Price, in France, 10 Frs. (post free 11 Frs.); other countries 12 Frs. post free.*

* *Payment should be made by post office order addressed to M. le Secrétaire Général du Comité Consultatiff International des Communications Téléphoniques a Grande Distance, 23 Avenue de Messine, Paris, 8e.*

"Electrical Engineering Economics." By D. J. Bolton, B.Sc., A.M.I.E.E. Chapman & Hall, Ltd. 21/- net.

In view of the importance of economics to engineering—in fact most engineering problems are essentially economic—it is strange that the literature of this aspect of engineering is so sparse. Indeed, as the author points out in his preface, most of the books on this subject have dealt only with production problems—costing, price fixing, and works management economy—and have given no account of the problems of economics arising after the stage of manufacture. The aim of the author of this work is, therefore, to explain the principles of the economics of use, or, as he calls it, "consumption economics."

With the object of making his work self-contained, the author has divided his subject into three parts. The first deals with general economic principles, and, as such, makes no claim to originality. But the information given therein regarding capital, interest, depreciation, and the various types of annuity and sinking fund is sufficient to enable a reader to master the main argument of the work without reference to other literature. ...

The second and third parts are concerned more particularly with the application of the economic principles enunciated in the first part to electrical engineering problems—from the standpoint of the utilisation of electrical energy, rather than from that of the manufacture of electrical apparatus. A rough distinction between the second and third parts assigns "Choice of Plant" to the former, and "Supply Problems" to the latter, but some overlapping between the two is inevitable.

Thus in the second part the economic basis of Kelvin's Law for Cables occupies the first chapter, while later chapters show how economic principles should determine the choice of motors of differing capital cost, efficiency, life and salvage value. This is followed by a similar treatment of transformers, while the peculiar conditions in the case of lamps are the subject of the last chapter of this part.

In the third part, problems of tariffs, load and diversity factor, power factor and so on receive attention, and in view of the great variety of tariffs in existence there is no need to stress the importance of their economic aspect.

A very valuable feature of the work is the number of worked examples, both in the text, and at the end of many of the chapters. Others, unworked, are included in an appendix. Important equations relating to simple and compound interest and tables for sinking fund deposits and for life of plant form other useful appendices.

The book is very readable and is a valuable addition to the literature of electrical engineering.

G. F. O'DELL.

"Automatic Telephony Simplified." By C. W. Brown, A.M.I.E.E. Sir Isaac Pitman & Sons, Ltd. 6/-.

This is an addition to the series of Telephone handbooks published by Sir I. Pitman & Sons, items of which have already been reviewed in these columns. The publication maintains the standard set by previous authors. The book is an excellent introduction to step-by-step automatic telephony and carries the student by easy stages to the elements of the system adopted for Metropolitan areas.

The arrangement of the text and method of treatment are excellent and the illustrations including the diagrams distinctly above the average. The book can be confidently recommended to students who are preparing for examinations that include Automatic Telephony in their syllabuses. Mr. Brown is an experienced teacher, a fact which is evident on reading his book.

B.O.A.

Kempe's Engineer's Year-Book for 1928. Thirty-fifth edition, with over 3,000 pages and 2,500 illustrations. Crosby Lockwood & Son. Price 30/- net.

There is no book of reference in the English language so useful to engineers of all classes as Kempe's; it is doubtful whether there is any volume in existence so packed full of reliable data and figures and so well arranged for ready reference. The developments in highway construction, steam power, electrical engineering, traction, internal combustion engines and their application to road and air traffic, have been kept pace with in a remarkable manner, while due regard has been paid to the advances made in marine engineering, gas and gaswork practice, mining and machine tool treament, etc. Many notes on practice become obsolete have been excised, but the book, as might be expected, is bigger than ever. It has for long been an understood thing among engineers when points are raised outside usual everyday practice to " look it up in Kempe," and the latest edition will not be found wanting. Our advice to those who treasure their old edition is to scrap it and buy a new copy, in the same way as they would treat an old machine which had served its time faithfully but which could not be brought up to date economically.

" A Text Book of Telegraphy." A. E. Stone, A.R.C.Sc. Macmillan & Co., Ltd., London. 20/- net.

The author's experience in teaching at the Polytechnic has resulted in his producing a text book on Telegraphy which will be regarded as a classic work on the subject. Intended primarily for the use of students preparing for examinations, the author has compiled a work which not only fully meets its original requirements, but will serve also as a valuable book of reference to engineers engaged in the practice of electrical communications generally.

The first seven chapters dealing with the fundamentals of electrical measurements contain a mass of information useful to the student and lead naturally up to the consideration of the application of the principles to working systems. The following chapters deal systematically with universal battery working, the simpler key systems, double current, duplex, central battery and concentrators, quadruplex, Wheatstone automatic, repeater and type printing systems. In the last-mentioned the subject is brought right up to-date and the descriptions cover all apparatus recently tried out and in operation by the British Post Office Department. Line work, protection from power circuits and lightning and the testing of lines are dealt with in three chapters, while a fourth gives an account of the construction of submarine cables and the methods of operation. It is a pity the author has omitted a description of the system of regenerative repeaters now used so successfully by cable companies, but this, we hope, will be included in a later edition. Mr. Stone should note also that a knot is a velocity and not a length. A very useful chapter on alternating currents and the propagation of signals along telegraph lines follows, and finally a brief summary of the principles involved in radio-telegraphy is included for the purpose of covering the Departmental examinations and City and Guilds syllabus. Two appendices are embodied at the end of the volume, one treating of the new system of voice-frequency telegraphs and the other giving a table of exponential and hyperbolic functions.

We can thoroughly recommend the book to our readers. The illustrations are excellently drawn and reproduced; the theoretical matter is ably dealt with, and the formulæ are evolved from first principles and clearly stated. A first class book on the subject.

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

PROMOTIONS.

Name.	Grade.	Promoted to	Date.
Lee, Lt.-Col. A. G., O.B.E., M.C.	Staff Engineer E-in-C.O.	Assistant Engineer-in-Chief.	14-5-28
Greenham, G. F., M.B.E.	Assistant Staff Engineer E-in-C.O.	Supty. Engineer S.E. District.	1-8-28
Hart, A. B.	Assistant Staff Engineer E-in-C.O.	Staff Engineer, E.-in-C.O.	1-11-28
Atkinson, J. W.	Assistant Suptg. Engineer, London	Supty. Engineer, N.E. District.	1-6-28
Brown, Major H., O.B.E.	Assistant Staff Engineer, E.-in-C.O.	Supty. Engineer, N. Mid. District.	1-6-28
Vickery, W.	Assistant Engineer S.W. District.	Executive Engineer, S.E. District.	11-4-28
Booth, C. F.	Inspector of Radio Section, E.-in-C.O.	Chief Insp. Radio Section, E.-in-C.O.	17-3-28
Sturgess, H. E.	Inspector Rugby Radio.	Chief Inspector Rubgy Radio.	14-2-27
Luckhurst, J. E.	Inspector Cupar Radio.	Chief Inspector, Cupar Radio.	23-6-27
Hollis, W. A.	S.W.I. N. Wales District.	Inspector, N. Wales District.	24-10-27
Milford, T. S.	S.W.I., N. Wales District.	Inspector, N. Wales District.	24-10-27
Holt, H. L.	S.W.I. S. Lancs. District.	Inspector, S. Lancs. District	9-5-27
Rigg, P. H.	S.W.I. N.E. District.	Inspector, N.E. District.	To be fixed later.

RETIREMENTS.

Name.	Districts.	Grade.	Date.
Sinnott, J., O.B.E.	E.-in-C.O.	Assistant Engineer-in-Chief.	30-4-28
Johnson, T. B.	N.E.	Superintending Engineer.	31-5-28
Twells, W. E.	E.-in-C.O.	Assistant Staff Engineer.	8-4-28
Gibbins, F. E.	N.E.	Assistant Suptg. Engineer.	6-4-28
McIntosh, D.		Assistant Engineer.	11-5-28
Gardner, A. W.	E.	Assistant Engineer.	25-3-28
Morris, A. C.	N. Mid.	Assistant Engineer.	1-6-28
Hill, G. A. D.	E.-in-C.O.	Assistant Engineer.	30-4-28
Lade, J. A.	S. Wa.	Chief Inspector.	30-4-28
Fowlds, W.	N. Wa.	Inspector.	3-3-28
Bucklitsch, J. H. C.	N.W.	Inspector.	23-2-28
Hosgood, J. S.	S. Wa.	Inspector.	30-3-28
Moon, F.	N.W.	Inspector.	16-3-28
Wallis, R. C.	N.E.	Inspector.	11-3-28
Marchant, J. A.,	London.	Inspector.	29-2-28

DEATHS.

Name.	District.	Grade.	Date.
Jackson, R. W.	N.	Assistant Engineer.	14-5-28
Yeadon, N.	E.-in-C.O.	Assistant Engineer.	8-4-28

TRANSFER.

Name.	From.	To	Date.
Payne, C. F.	Inspector S. Lancs. District.	N.W. District.	8-3-28
Angus, J.	Inspector S. Lancs. District.	N.W. District.	

APPOINTMENTS.

Name.		Appointed to	
Gomersall, E., O.B.E.		Deputy Suptg. Engineer, London.	1-6-28
Hunt, R. H.	Probationary Inspector N. Mid.	Inspector, N. Mid.	29-2-28
Bourdeaux, N.	,, ,, E.-in-C.O.	Inspector, E.-in-C.O.	1-5-28
Arman, L. T.	,, ,, ,,	Inspector, E.-in-C.O.	,,
Stacey, P. A.	,, ,, ,,	,, E.-in-C.O.	,,
Simpson, C.	,, N. Ireland	,, N. Ireland	,,
Young, J. E.	,, ,, London.	,, London	,,
Dore, L. J.	,, ,, N. Waels	,, N. Wales.	,,
Devereaux, R. C.	,, ,, London.	,, London	,,
Shrubsall, F. W.	,, ,, London.	,, London	,,
Henderson, V. R.	,, ,, E.-in-C.O.	,, E.-in-C.O.	,,
Barrett, H.	,, ,, London.	,, London	,,
Barry, C.	,, ,, N.W.	,, N.W.	,,
Blackburn, E.	,, ,, N.E.	,, N.E.	,,
Reed, T. F.	,, ,, S.W.	,, S.W.	,,
Waters, H. S.	,, ,, S.E.	,, S.E.	,,
Howarth, H.	,, ,, N.W.	,, N.W.	,,

CLERICAL ESTABLISHMENT.

PROMOTIONS.

Name.	Rank.	Promoted to.	Date.
Whitehead, J. H.	Higher Clerical Officer. N. Wales District.	Staff Officer, N. W. District.	15-4-28
French, J. J.	Acting Higher Clerical Officer, London.	Higher Clerical Officer, London.	13-4-28
Coster, F. J.	Clerical Officer, London.	Acting Higher Clerical Officer, London.	18-4-28
Coster, F. J.	Acting Higher Clerical Officer, London.	Higher Clerical Officer, London.	1-6-28
Emmett, H. H.	Clerical Officer.	Acting Higher Clerical Officer, London.	1-6-28
Lay, J. W.	Clerical Officer, E. District.	Higher Clerical Officer, E. District.	22-4-28
Smith, W. B.	Clerical Officer, S. Lancs.	Higher Clerical Officer, Ireland N.	1-5-28

Retirements.

Name.	Grade.		Date.
Terrill, F. G. A.	Executive Officer, London.		12-4-28
Mullens, H. W.	Higher Clerical Officer, London.		31-5-28
Cousins, E. W.	Higher Clerical Officer, London.		30-6-28

TRANSFERS

Name.	Rank.	From	To	Date.
Adams, H. G.	Higher Clerical Officer	E. District.	N. Wa. District.	22-4-28

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Colombo,
Ceylon.

CENTRAL LIBRARY.

The following books have been added to the Central Library. Applications for the loan of same should be addressed to the Librarian, Institution of P.O. Electrical Engineers, Alder House, E.C.1.

List IV.

No.	*Title.*	*Author.*
867	Practical Television	E. T. Larner.
868	Modern Road Construction ...	F. Wood.
869	Electrical Engineering Economies	D. J. Bolton.
870	Radio Communication	J. H. Morecroft.
871	Industrial Telephony	J. Lee.
872	Automatic Telephony	C. W. Brown.

THE
Post Office Electrical Engineers' Journal

PICTURE TELEGRAPHY.

ALTHOUGH there are several methods of transmitting print and line drawings over telegraph wires, this article is limited to those systems which receive photographically.

The transmission of print and pictures over a telegraph line is not of recent origin, the first attempts actually dating from 1843, but the transmission of really good pictures is a modern achievement.

A photograph is considered critically sharp if the smallest element does not exceed the size of a dot one two-hundredth of an inch or, say, one-eighth of a millimetre in diameter. Systems which reproduce a picture coarser than this fall off in perfection proportionately, although they may be suitable for the purpose for which they are required.

All systems require a sending apparatus, a receiving apparatus, means for keeping the movements of the sending and receiving apparatus in synchronism and a line or medium for connecting the sending to the receiving apparatus.

The sending apparatus provides means for scanning the picture or print in closely spaced lines and converting the light and dark portions into an electric current whose strength is proportional to the light and shade on the picture. An alternating current is generally chosen for this purpose, as being more easily transmitted over a telephone line, its frequency being chosen to suit the line characteristics. The higher the carrier frequency the quicker can any given picture be sent for the same fineness of detail. It will at once be seen that radio offers advantages, since generally a higher carrier frequency can be used; in the case of line transmission the picture carrier is modulated in accordance with the light and shade of the picture, whilst for radio transmission this modulated picture carrier in turn modulates the radio waves.

The Sending Apparatus.—This consists of a source of light which can be focussed on the picture as a point. The picture is clamped to a drum which can be rotated and traversed as a nut along a screw thread. The point of light therefore scans the picture in the form of a spiral. In the case of the " Bell " system the picture is prepared in the form of a transparent film about seven inches by five inches and the light passes through the film and is concentrated by a lens on to a photo-cell, the amount of light passing being governed by the light and dark portions of the film. In the case of the " Belin " and " Siemens-Carolus " systems interrupted light is used, the number of interruptions per second being the carrier frequency. In the former system the light spot is of appreciable size on the picture, a point of the picture being taken and concentrated on to the photo-cell, whilst in the latter system the light falls as a point about two-tenths of a millimetre in diameter on the drum, the reflected light being caught in the photo-cell.

The photo-cell consists of an evacuated glass vessel on one wall of which is a deposit of potassium hydride; this deposit is connected to a lead passing through the glass and forms the cathode, the potassium emitting electrons in proportion to the amount of light falling on it. The anode consists of a metal plate or wire grid also with an external connection. A battery of suitable electromotive force and correct polarity converts the emitted electrons into a flow of current and by suitable coupling this current can be made to vary the grid potential of the first valve of a valve amplifier. Care must be taken not to use too high a priming voltage for the photo-cell as, if so, ionisation will occur and the electron emission will not be controlled by the light. In the case of the cell used in the "Siemens-Carolus" system, from 100 to about 150 volts, depending on the cell, will be found suitable; the votage is adjusted until ionisation occurs, and then reduced about 10 volts. The maximum current even for white light is very small, being of the order of 10^{-8} amperes. The cell behaves to coloured light much as an ordinary photographic plate does, red light corresponding to black, and blue and ultra violet to white.

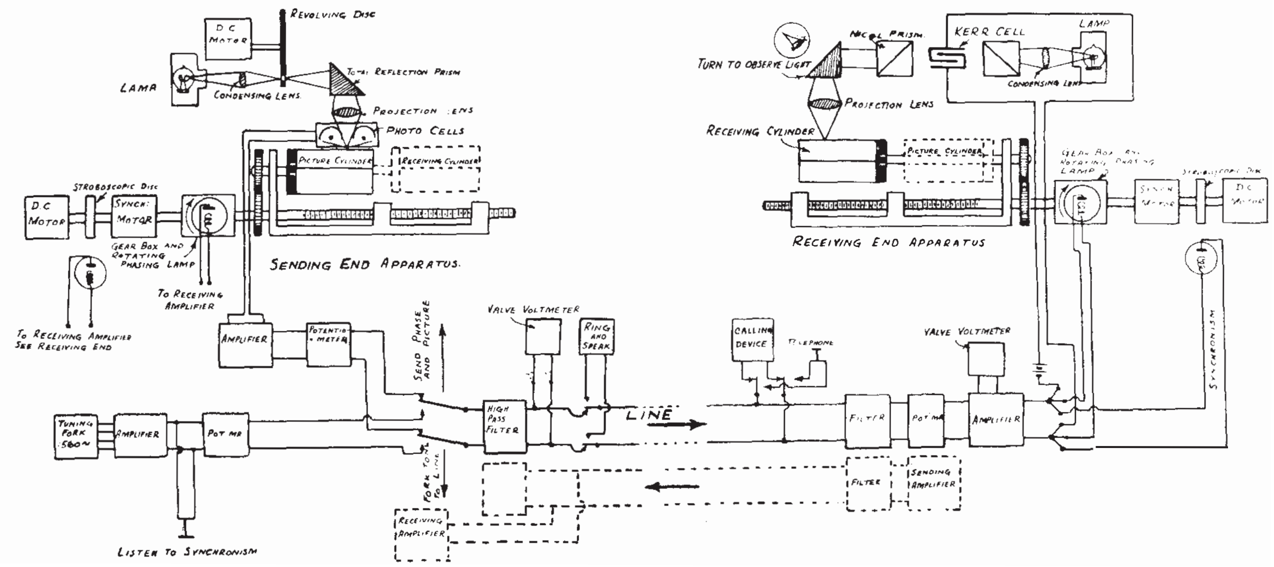

FIG. 1.—SIEMENS-CAROLUS SYSTEM: SCHEMATIC DIAGRAM.

In the Siemens system a four valve resistance-capacity coupled amplifier, fitted with potentiometers for controlling the amplification, amplifies the photo-cell current and puts it on the telephone line through an output transformer. A good adjustment is 0.3 volts for white light on an 800 ohm impedance line. Similar arrangements are used in the case of the Belin system. All leads and the amplifier must be carefully screened from interference.

In the case of the "Bell" system a two valve battery-coupled amplifier is used, the output voltage from the second valve being used to modulate an oscillator produced carrier current on the grid of a third and final valve which feeds the line through a transformer. In this system the voltage applied to the first valve from the photo-cell is of the order of 30 to 40 milli-volts.

In the Belin system the light is interrupted from 800 to 900 times a second. In the Siemens system an automobile headlight type of lamp, with its filament displaced from the centre so as not to produce two images and rated at 6 volts, is overrun at about 7 to 8 volts and controlled by a series resistance off a 12 volt battery. For normal telephone lines the light interruptions are 1300 per second.

A high pass filter cutting off below half the carrier frequency, in this case 650 cycles per second, is inserted between the output transformer and the line.

The carrier frequency can be changed from 1300 cycles per second to any reasonable value, by either changing the speed of the disc-driving motor by altering the series resistance, or another disc with a different number of holes can be used. The carrier frequency can be adjusted, either by observing a tachometer coupled to the interrupting disc or by listening to the carrier frequency in a telephone and also at the same time to a 1300 cycle tuning-fork.

The Receiving Apparatus.—The line is connected *via* a potentiometer which is used to control the incoming power to an amplifier which amplifies the line current to a value suitable for operating the receiving apparatus.

The picture is received on a photographic film, which is mounted on a drum and is rotated and traversed in a similar manner to the sending drum. The drum is of necessity enclosed in a light-tight case, a spot of light being projected on the drum by an optical system from a suitable source of light. The intensity of the light is controlled by the received current.

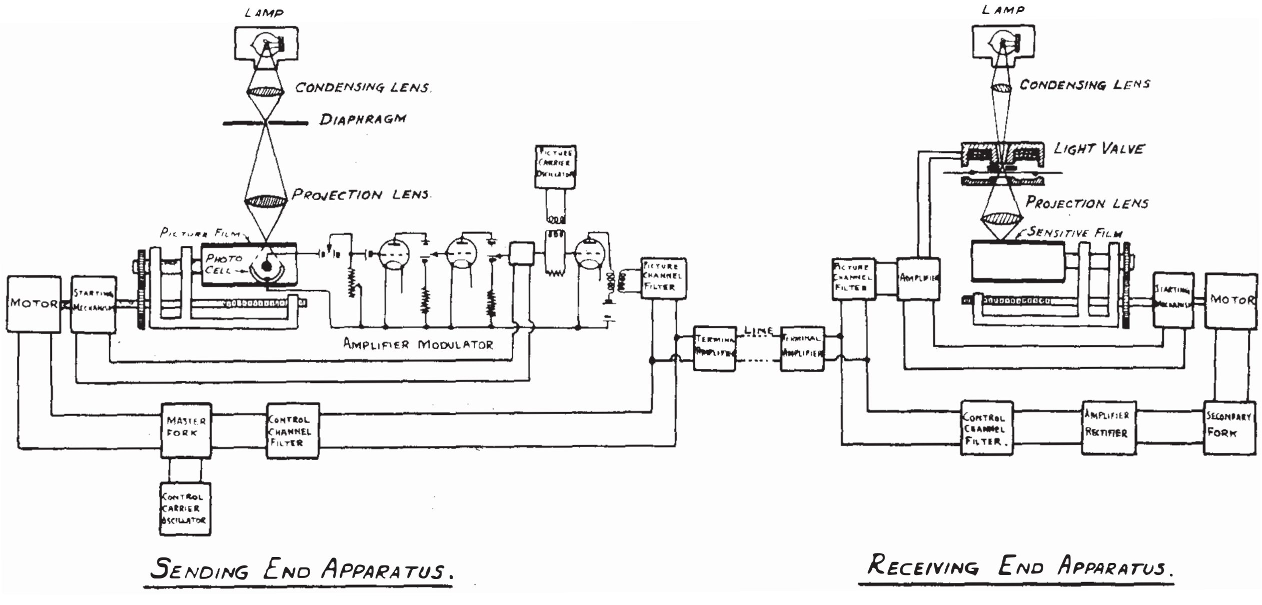

FIG. 2.—" BELL " SYSTEM: SCHEMATIC DIAGRAM.

In the case of the Belin system, the carrier current is rectified and operates the mirror of a " Dubois " oscillograph; the tilting of the mirror throws more or less light through a special aperture and lens on to the film.

In the Bell system, the amplified current is passed through a narrow ribbon type conductor in a strong magnetic field; the ribbon is so arranged that it normally covers an aperture through which the light reaches the photographic film. The ribbon will vibrate in accordance with the frequency and amplitude of the received current; the greater the amplitude the greater the amount of light which will go through. In the case where the light aperture is focussed on the film, lines of constant intensity and varying width will be produced. In the second type of reception, diffused light falls on the film; in this case lines of constant width and varying intensity are formed. This latter type of reception is more suited to photographic manipulation, whilst in the first type if the lines are suitably spaced, say, 60 to the inch, the negative may be used to print directly on the zinc typographic plate. In the latter system a hundred lines to the inch are used and the usual screen is used for half-tone reproduction. The time of transmission of a 5 inch by 7 inch picture is about seven minutes.

In the Siemens-Carolus system a two valve amplifier transforms the line current to a voltage (for white light sent) of from 400 to 600 volts. This voltage is applied, together with a direct priming voltage of from 70 to 200 volts, to the electrodes of a Kerr or Carolus cell which consists of two brass terminals immersed in nitrobenzol in a glass vessel. In the earlier type of cell the electrode gap is adjustable and consists of one gap, whilst in the later type the electrodes are fixed and the gap is a multiple one like a multi-plate condenser. The adjustable type requires the higher voltages and the fixed type the lower voltages mentioned. The fixed type has the advantage that they may be constructed, filled and hermetically sealed in the works, whilst the adjustable type has to be cleaned and filled *in situ*.

Light from a source similar to that used at the transmitting end is passed through lenses and two Nicol prisms, between which the Kerr cell is placed, further lenses and prisms focus the light as a spot on the film. The Nicol prisms are set so as to cut off all light from being transmitted, each prism being set to polarise the light at right angles to the other. When voltage is applied to the Kerr cell, the plane of polarisation of the light is twisted, thus allowing more light to get through. The Kerr cell thus acts as a light valve without inertia and can therefore work up to any required carrier frequency, such as might be possible with radio transmission. The law followed (light against voltage applied) is very similar to that of the anode current of a valve where anode current corresponds to light and grid volts to volts across the electrodes of the Kerr cell. In the Belin and Siemens systems the films are fixed to drums enclosed in light-tight cases in the dark room; they are then brought out into the operating room and attached to the picture apparatus as required.

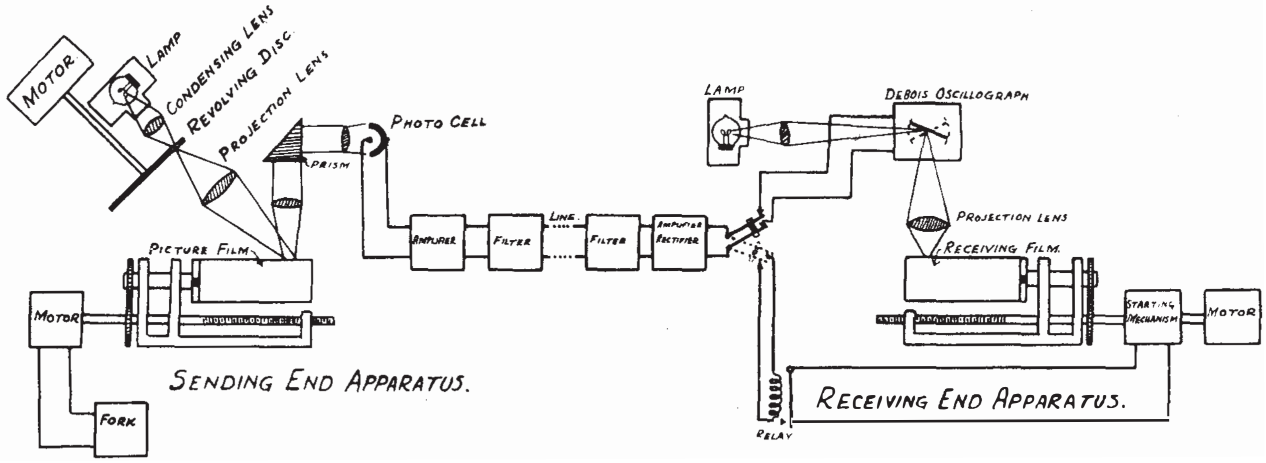

FIG. 3.—BELIN SYSTEM: SCHEMATIC DIAGRAM.

Synchronisation.—It is essential not only that the drum at the sending and receiving ends should run at a uniform speed but also that these speeds should be identical. The following quotation is taken from the "Bell System Technical Journal," Vol. IV., No. 2, April, 1925: "Were it possible to have two forks at widely separated points running at exactly the same speed, the problem of synchronizing would be immediately solved. Actually this is not practical, since variations of speed with temperature and other causes prevent the two forks from operating closely enough together for this purpose." In the Siemens system this problem has been satisfactorily solved. At each end of the circuit is a valve-driven 1560 cycle per second tuning-fork in a heavy steel case placed in a water-jacketed can, the outside of which is surrounded with cotton wool and the whole placed in a large wooden box. The water jacket and cotton wool serve to keep the temperature of the fork constant or at any rate prevent any rapid changes of temperature. The valve driving the fork is of the bright emitter type, with means for adjusting its filament current to a known and prearranged value. The method of adjusting synchronism is to send fork tone on the line, amplify it at the receiving end so as to light a neon lamp which illuminates a stroboscopic disc attached to the motor driving shaft. The small speed adjustment required to keep the marks on the disc from changing in position over a period of three to five minutes is made in the following manner. The condenser coupling the grid and plate circuits of the fork is increased in value which increases the reaction and the amplitude swing of the fork. This slows the fork down a fraction of a cycle per second; decreasing the value of the capacity slightly increases the speed of the fork. Once set, the condenser adjustment requires little change, if any, from day to day. The fork tone is amplified two further stages, the last stage consisting of three power valves in parallel, the output of which is transformed into the stator of a synchronous motor or alternator which in turn is directly coupled to the direct current driving motor. Provided the fluctuations of voltage in the driving motor circuit are not excessive the synchronous motor will hold the speed constant. In the case of the "Bell" system, at the sending end a tuning fork, similar to those used for driving the phonic motor of the Baudot Telegraph, drives the picture apparatus in a similar manner but in addition is used to modulate a 400 cycle per second carrier wave, which is sent over the line to the receiving end where it is amplified and rectified and serves to hold a similar fork and phonic motor in perfect synchronism. The picture carrier and the fork carrier are separated by means of filters from interfering with one another at both the sending and receiving ends. If the two ends are not in synchronism the picture will be skewed, that is to say, instead of being a rectangle it will be a parallelogram.

Phasing.—In the Siemens system the driving apparatus is running continuously; the sending or receiving picture drums are arranged so that they can be coupled to the driving shaft by means of a magnetic clutch at one point only in the revolution. Providing the speed remains constant, no matter how often the sending or receiving end drums are started and stopped, they will always be in the same relative positions at the two ends. It is necessary therefore before starting the day's work to see that the joints in the picture at the sending end and the receiving end are in the same relative position. This is done as follows: on the picture clip at the sending end are two white lines, whilst the rest of the drum is black at this place; on rotating the drum without traversing it two rushes of picture carrier current close together once per revolution will be sent to line. At the receiving end, the amplifier is switched so as to light a small neon lamp which rotates at picture speed; if this lights opposite a certain mark nothing more has to be done; if, on the other hand, it does not, it is necessary to shift the phase until it does. This may be accomplished in two ways; for large displacements the driving motor resistance is changed so as to pull the motor out of synchronism either above or below synchronous speed, according as the phasing point has to be advanced or retarded; the resistance is restored to normal as soon as the correct point has been reached. The second method is generally used for small displacements, and for this the stator of the synchronous motor is rotated by means of a hand wheel suitably geared for the purpose.

In the Bell, and also in the case of the Belin systems, phasing is unnecessary, as a starting signal is sent on the line. In the case of the Belin system the picture drum is white, except where the clips are fixed. The carrier current is therefore interrupted at this point, as black sends no current from the photo-cell. At the receiving end, when the operator is told to start, a key is held down which connects an amplifier rectifier to a telegraph relay which releases as soon as the line current ceases and operates a clutch

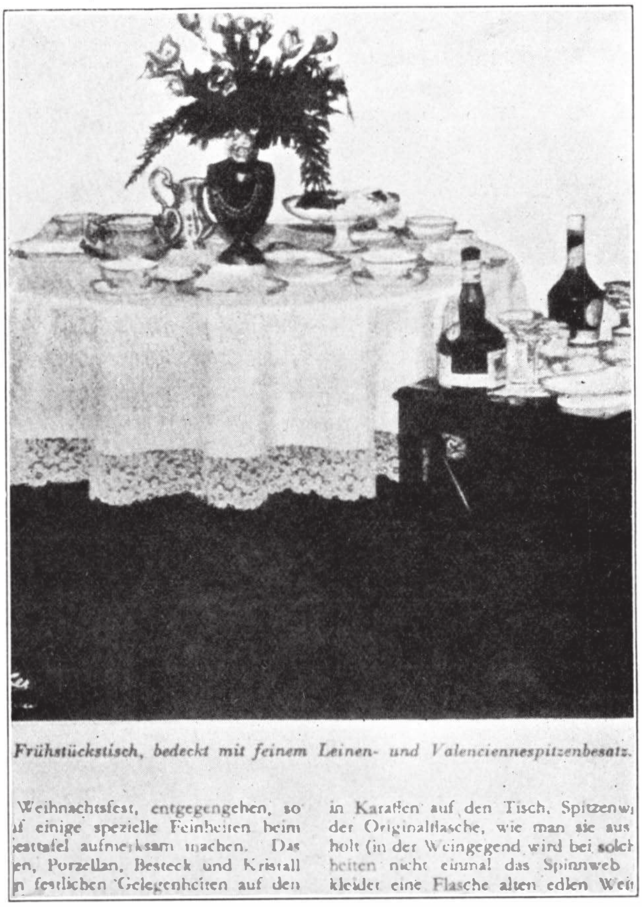
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FIG. 4.—PICTURE AS RECEIVED IN LONDON FROM BERLIN.

connecting the picture drum to the driving mechanism. The picture drum, being set at rest at the correct position, starts off at the right position.

Signalling and Speaking.—In the case of the Siemens system arrangements are provided for operating the set either over a two-wire telephone line or over a four-wire line; in the latter case a picture can be sent and received simultaneously at each end. At the receiving end, in the case of a four-wire connection, an amplifier rectifier and relay are permanently connected across the line and are operated by 500-cycle modulated by 25 cycles per second ringing current, so that in an emergency the distant end may be called even during the transmission of a picture, although this of course spoils the picture. Speaking is done on one line and listening on the other line for four-wire working, but, by throwing a key normal, two-wire working of the telephone is obtained, and in this case 17-cycle ringing may be sent and received. A thermionic voltmeter is also provided, which is suitable for measuring the sent and received picture voltages, as well as ammeters and voltmeters for measuring currents and voltages of the various batteries supplying the lamp and valve filaments, anodes, motors, etc.

Transmission Line Requirements. — The carrier current frequency chosen for picture transmission should be as high as possible, having due regard to the characteristics of the line. As one of the principal requirements of a picture is sharpness, that is, the transit from white to black in the shortest possible interval of time, one line requirement is that the carrier current be established or extinguished quickly. This can only be the case when all the frequencies transmitted for the picture arrive at the receiving end at the same time. A lump or coil-loaded line tends to have a longer time for transmission of the higher frequencies, until at the cut-off or critical frequency nothing is transmitted.

The following are also necessary conditions for good pictures :—

(1) The line must be free from momentary or other interruptions.

(2) The attenuation of the line must not vary appreciably throughout its transmission range.

(3) The attenuation must be constant and not vary from moment to moment.

(4) The line must be free from echoes and other irregularities.

(5) The line must be reasonably free from cross-talk, ringing induction, telegraph induction and noise.

(6) The telephone repeaters must not introduce spurious frequencies by modulating the carrier wave.

(7) The cut-off frequency should be as high as possible.

The carrier frequency should not exceed half the cut-off frequency, and high pass filters should be provided at the sending and receiving ends to cut off all below about half the carrier frequency.

The nominal time of transmission "t" seconds of a frequency $\frac{\omega}{2\pi}$ cycles per second is given approximately by the formula :—

$$t = \frac{2N}{\omega_c \sqrt{1 - \frac{\omega^2}{\omega_c^2}}} = \frac{2l}{d \cdot \omega_c \sqrt{1 - \frac{\omega^2}{\omega_c^2}}}$$

where N is the number of loading sections, $\frac{\omega_c}{2\pi}$ the critical frequency, "l" is the length of the line and "d" the coil spacing, both measured in the same units, for example, miles or, alternatively, kilometres.

Taking the Siemens system as an example (the same reasoning applies to other systems); the carrier frequency usually used is 1300 cycles per second. The drum, whose circumference is 22 centimetres, rotates once in 1.33 seconds; hence the movement is 0.165 millimetre in one millisecond, or 0.127 millimetres in one cycle of the carrier current. The traverse is 0.2 millimetres per revolution, if the same sharpness is to be obtained vertically and horizontally on the picture; then the building-up time of the carrier should not exceed 0.2/0.165 or about 1.2 milliseconds. This building-up time may be roughly reckoned as the difference in the time of transmission over the line of 650 cycles per second and the carrier frequency 1300 cycles per second and may be calculated by the above formula. Should this time be exceeded it is possible to insert special time correction networks in the line. These have been developed both in America and Germany. The calculated difference in time of 1300 cycles and 650 cycles on an experimental picture circuit set up between London and Berlin and about 1000 miles long was 1.39 milli-seconds, whilst the total time for 1300 cycles was about 50 milli-seconds.

The Photographic Requirements.—Whilst it is easy to transmit pictures on any of the three systems mentioned a certain amount of photographic skill and experience are necessary for the transmission and reproduction of good pictures. In the case of the "Bell" system, the correct density, etc., is necessary in the positive prepared for transmission. In the case of the Belin and the Siemens systems the following points require attention: the setting of the sent voltage for the light part of the picture at the sending end, and the setting of the light and amplification at the receiving end; the development, fixing, hardening and drying of the films.

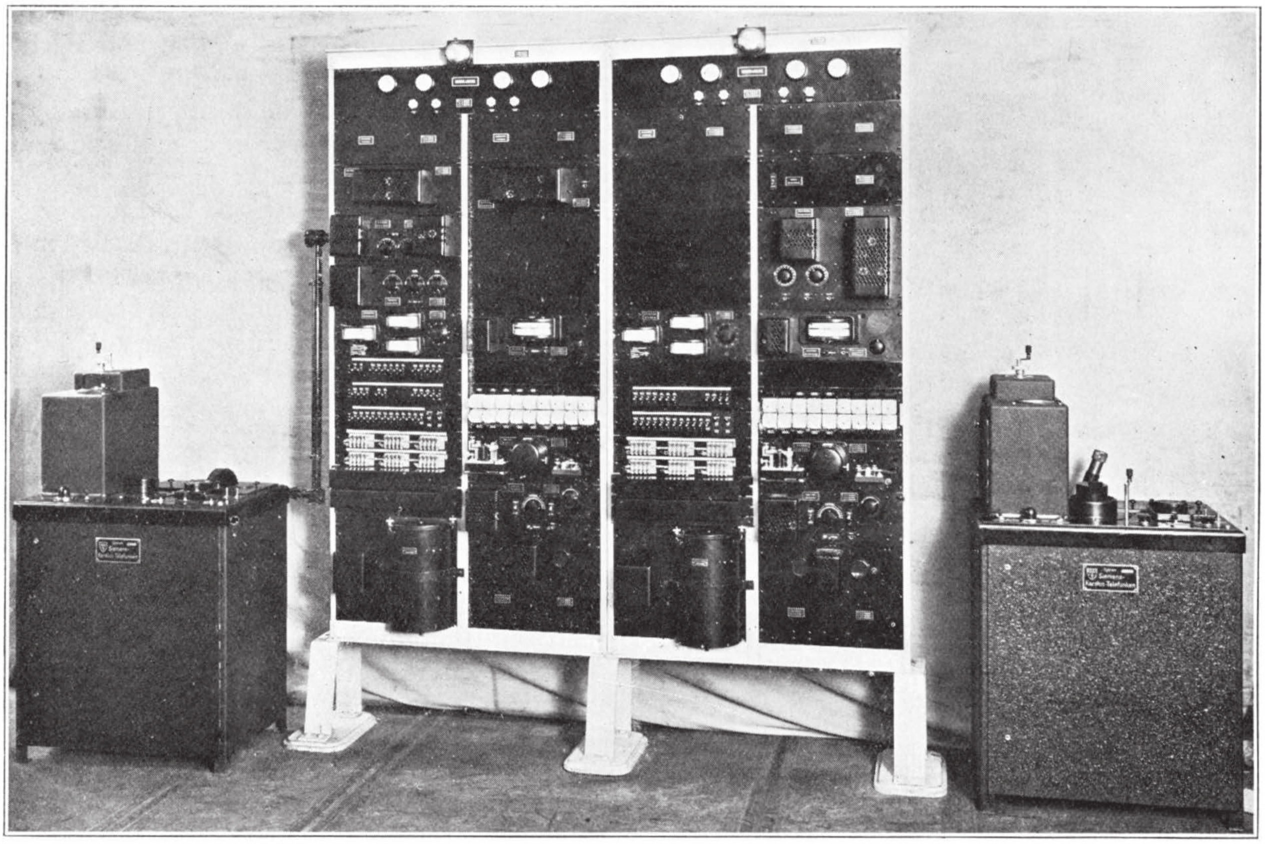

Fig. 5.—Siemens-Carolus Set (Sending and Receiving ends) as recently supplied to Japan. Similar to those to be supplied to certain English Newspapers.

The printing of the films, either by contact or enlargement on a suitable grade of paper at the receiving end, and giving the correct exposure and development to these prints are matters which all require photographic skill and experience if the best results are to be obtained. If anything is worth doing, it is worth doing well!

A photograph is reckoned to be critically sharp if the smallest dot does not exceed a diameter of about 1/200 of an inch; in all picture transmission systems some sharpness must of necessity be lost. The Bell system scans at 100 lines to the inch and the Siemens at 127. A picture about 4 inches by 8 inches is transmitted in about 12 minutes on the Siemens system with a carrier of 1300 cycles, and a picture 7 inches by 5 inches in 7 minutes on the Bell system. The Belin system uses a carrier of 800 to 900 cycles and the pictures are transmitted about the same size and speed.

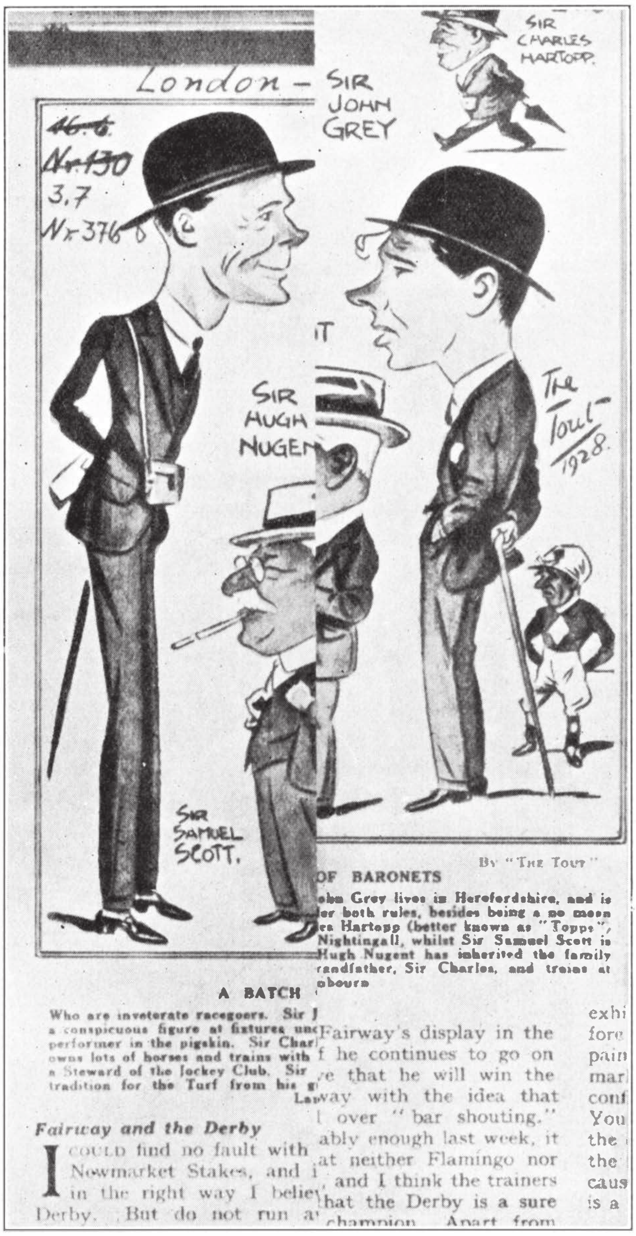
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Fig. 6.—Picture transmitted from Sending to Receiving Apparatus in London.

The right hand side through an artificial line and the left through the line, London to Berlin and back. The displacement is due to the propagation time of the signals over the line (104 milli-seconds) and the extra blurring effect to the distortion produced by the line.

There are systems in course of development which are not mentioned here. Several are designed to transmit relatively rough diagrams for reception in the home by radio on relatively cheap and inexpensive apparatus, using such methods as the decomposition of a chemical to give the light and shade of the picture instead of the photographic methods described. There are other systems primarily designed to transmit black and white print over the radio at high speed, but space and time prevent a description of them.

The Author appreciates the fact that owing to the quick rate of development in the different systems the descriptions given here are not up to date; at any rate, he is aware of improvements in important details in at least two of the systems described which will go some way to facilitate operating.

The Author has been engaged in trials on the Siemens system between London and Berlin on a line about 1000 miles in length. A few of the troubles met with may be of interest in showing that at any rate some of the troubles are not in the picture apparatus itself.

(1) It was found difficult to hold synchronism with the driving motor supposed to be running off the 120-volt telegraph battery during the daytime, though in the evening it ran satisfactorily. The motor was changed over to the lighting system and ran well. It was found afterwards that during the day the supply came from motor-generators and not from the telegraph battery and there were considerable fluctuations in the voltage.

(2) Ringing induction from harmonics in 17-cycle ringing current caused interference on the pictures occasionally. This induction originated between Canterbury and London and came from the side circuits, the picture circuit being the phantom. The trouble was removed by changing to other pairs.

(3) Circuit frequently interrupted for short intervals. Cause found in the plugs and cords used to cut out the 4-wire termination on the repeater; one plug fitted the jack badly.

(4) Wires run to cut out the cords. A peculiar overshoot in going from black to white was noticed. It was eventually traced to cross-talk between the input and the output of the repeater in these wires. Trouble removed when cause discovered.

(5) A fifty cycle per second modulation of the picture carrier wave was experienced frequently, particularly during the daytime. This was traced to the anode current supply at two repeater stations. When a certain rotary converter supplied the anode current the effect took place, but when supplied by a motor-generator

off the filament battery it did not take place. The offending repeater stations were discovered by a process of elimination, by looping back the line at each in turn and receiving a picture at the same end as the sending end. When good at one repeater station and faulty at the next, the last station brought in was located as the cause of the trouble. The trouble was removed by using the anode supply which did not cause trouble when pictures were being transmitted.

(6) Excessive voltage priming the photo-cell causes streaks like shadows across the picture.

(7) Failure to synchronise the ends causes the picture to be a parallelogram instead of a rectangle.

(8) Failure to phase will cause the joint in the transmitted picture to come in the received picture instead of at the joint. One day Berlin was in a hurry and London chanced the phase being correct. Actually, just the edge of the clip showed; this, of course, was luck.

(9) At first, run-down filament batteries was a source of trouble; changing to larger cells removed the cause.

Thanks are due to Messrs. Belin and to Messrs. Siemens and Halske for the information furnished in this article, and also to Col. Shreeve, the representative of the Bell Telephone Companies in this country, for the particulars of the Bell system.

E.S.R.

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SOME NOTES ON ARRIVAL CURVES AND THEORETICAL TELEGRAPH SPEEDS.

W. T. PALMER, B.Sc., Wh.Ex., A.M.I.E.E., and H. J. JOSEPHS.

SYNOPSIS. — The following describes a method for defining the theoretical maximum speed of a circuit which employs a rectangular impressed voltage wave for the signal elements and discusses the effect of the terminal conditions on this speed. Some examples of actual circuits having different characteristics are treated and experimentally obtained arrival curves are given as illustrations. Formulæ are deduced including leakance and inductance factors which will enable the theoretical maximum telegraphic speed to be determined in any particular case. The introduction of the " Permalloy " loaded cable has presented the possibility of telegraphic transmission limited only by the effects of irregular causes.

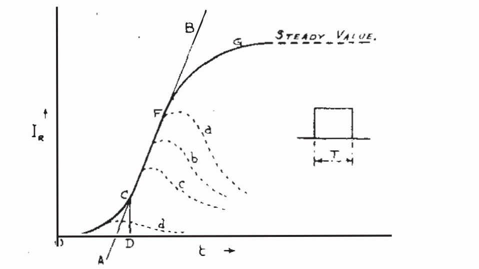
The maximum theoretical speed of signalling in a telegraph system is limited by the maximum allowable departure of the shape of the received signal from that of the transmitted signal. The factors causing the distortion of the signals can be divided into two classes:—

(*a*) Distortion due to the line itself.

(*b*) Distortion due to irregular causes, such as variation of battery voltage, chattering of relays, interference from external sources, etc.

It is thus seen that the development of any mathematical expression for the maximum speed of signalling when the effects of both (*a*) and (*b*) are present would involve an exact knowledge of the behaviour of all these separate factors. A reference to the work already done in this direction shows the difficulty of this problem. The limitation of speed imposed by (*a*) alone may be regarded as the maximum theoretical speed possible on any given line. With regard to the effects mentioned in (*b*) experimental methods can be developed for any particular case to enable some of the separate factors to be determined with a certain degree of accuracy. Empirical formulæ can then be formed to allow for the effects of (*b*) on the maximum theoretical speed. In the following paragraphs a simple method is shown by which the reduction of speed due to the combined effects of (*b*) in any given case, can be obtained.

Consider the case of a very long circuit, such as that of an unloaded ocean cable, the deciding factors in limiting the speed of signalling are those mentioned in (*a*). For very short lines, less than 50 miles, say, the limitation of speed is chiefly fixed by the effects of (*b*); but the majority of cases fall between these two extremes, and the actual speed obtainable is limited partly by (*a*) and partly by (*b*).



a, b, c and d represent elementary arrival dot signals.

FIG. 1.

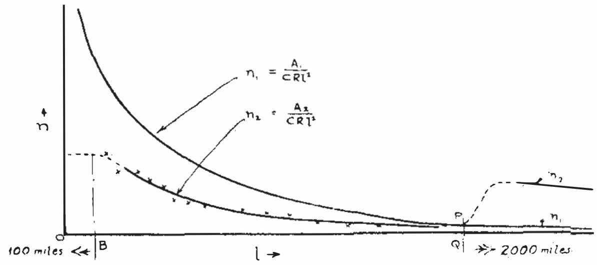


FIG. 2.

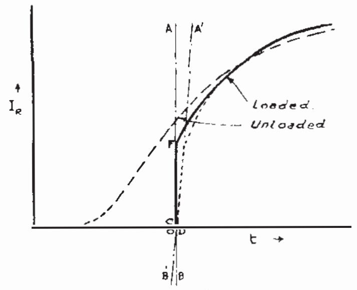


FIG. 4

Consider Fig. **1**. The full curve OCFG is a typical example of the way in which the current grows at the receiving end of a line, whatever its length, or terminal apparatus in use, when a sudden steady e.m.f. V is applied at the sending end. (See Appendix I.).

The line of greatest slope AB can be easily drawn and it will be found to coincide with a portion CF of the curve. From C, the point at which AB leaves the curve, the ordinate CD is drawn and it can be seen that for times of contact greater than OD the elementary signals *a*, *b*, etc., are similar in shape, but for times smaller than OD the elementary signals tend to flatten rapidly and successive signals will thus overlap. OD can be taken as a measure of the smallest time of contact for a current impulse permissible if good legible signals are to be received, and assuming the receiving apparatus to have the necessary sensitivity. (See Appendix II.). If the number of signal elements per letter required by the particular code used be known, then from the length of time represented by OD the maximum theoretical speed in letters per minute, *n*, can be calculated. Further, it will be found that the maximum speeds calculated by this method for different lengths of unloaded cable, having the same electrical constants, obey a law of the form

$$n_1 = \frac{A_1}{CRl^2} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(1)$$

where A_1 is a constant, C = capacity per unit length, R = resistance per unit length and l = total length of cable.

Having found n_1 from Fig. **1** as explained, the value of A_1 is readily calculated by equation (1). Now, if the actual working speeds, n_2, obtained on different lengths of the same type of cable using similar terminal apparatus be plotted and the mean curve drawn through them, this curve is found to be also of the form

$$n_2 = \frac{A_2}{CRl^2} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(2)$$

and A_2 is obtained from points on the curve. See Fig. **2**, where the crosses represent experimentally obtained points and the dotted portions are possible continuations not verified by experiment.

Thus the *total reduction of speed* produced by the combined effects of (*b*)—and considered for lengths less than that represented by OQ in

Fig. **2**—appears to follow a similar law to that of the famous " KR " law and is given by

$$n_1 - n_2 = \frac{A_3}{CRl^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where $A_3 = A_1 - A_2$.

As examples of the application of the foregoing consider the following cases :—

(1) *Single U/G Conductor,* having

$C = 0.11\ \mu$F. per mile
$R = 12.5$ ohms ,, ,,

Taking l at intervals of 100 miles the upper curve shown in Fig. **3** has been constructed by using equation (1), the value of $A_1 = 67.5$ in that equation, being obtained by the method previously described. The lower curve in this figure is one obtained from observed values of maximum speeds obtained on a single wire circuit (between London and Glasgow) with approximately the above electrical constants and gives by equation (2) $A_2 = 40$, (taking five letters one word on the average). Hence the reduction of speed in letters per minute produced by the irregular causes for any length l of this circuit is represented by

$$\frac{67.5 - 40}{CRl^2} = \frac{27.5}{CRl^2} = \frac{20 \times 10^6}{l^2}$$

if C is expressed in microfarads. Thus whilst for 600 miles we get only a total reduction of 56 letters per minute from the theoretically possible speed, we find that for a length of 100 miles the reduction is 2,000 letters per minute, or 36 times as much.

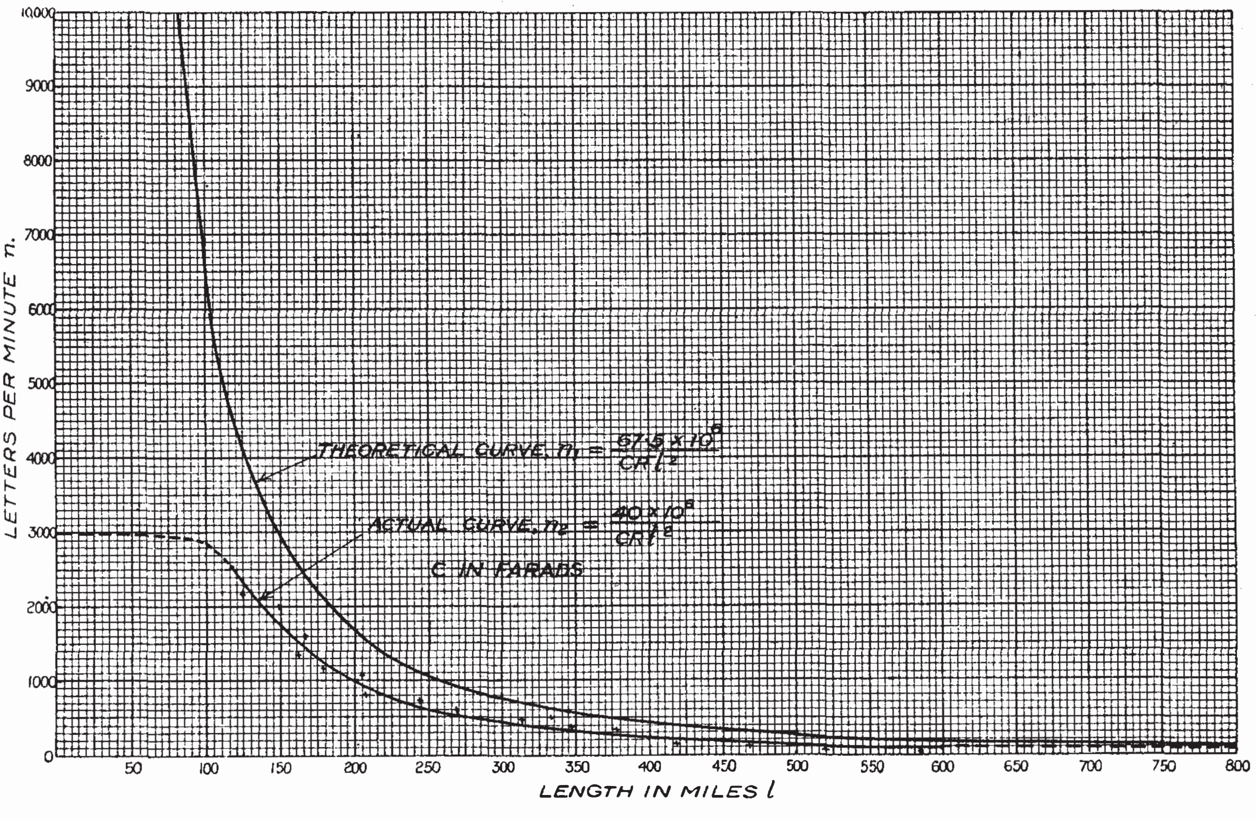


Fig. **3**.—Curves showing Theoretical Maximum Speed and Actual Speed.

(2) *Long Ocean Cable,* having

$C = 0.409\ \mu$F. per naut.
$R = 2.578$ ohms per naut.

Such cables are usually more than 1000 nauts in length and the elementary curve in Fig. **1** rises very slowly, so that the time OD is comparatively long. By means of large condensers at the ends of the cable and other terminal devices the curve can be made a little steeper though less in amplitude and the time OD decreased, thus increasing the theoretical speed of the cable. The Imperial No. 2 cable has for the major part of its length—2108 nauts—approximately the constants given above. Then *neglecting the effect of terminal arrangements* used for decreasing the time OD we get by equation (1) a theoretical speed of working in letters per minute imposed by the cable itself of only

$$n_1 = \frac{97}{CRl^2}$$

Malcolm has shown, by means of Heaviside's Expansion Theorem how to construct the curve shown in Fig. **1** when the effects of the signalling condensers are included. Such a curve drawn for the cable just considered gives by equation (1)

$$n_1 \fallingdotseq \frac{500}{CRl^2}$$

which represents an *increase* of about 500% over the limit imposed by (*a*) and accounts for the crossing of the curves at the point P in Fig. **2** for large values of *l*.

By increasing the sensitivity of the receiving apparatus and by use of shaping networks the value of $A_1 = 500$ can be slightly increased, and the actual working curve for n_2 will be raised a little above that shown in the figure. It has not been possible to make a sufficient number of experiments to obtain for such long cables the information corresponding to that given in Fig. **3**.

(3) *"Encroachment" or "Margin" and Loaded Telegraph Cables.* (See Appendix III.).

The separate factors mentioned in (*b*) have been studied by M. Collet,* H. Salinger,† and Messrs. Nyquist, Shanck and Cory‡ and the term "encroachment" or "margin" has been used to denote the amount by which parasitic or interfering currents modulate the received signal. The greater the slope of the tangent AB, shown in Fig. **1**, the more will the effect of "encroachment" be diminished. In the limit if the tangent AB is made vertical, the "encroachment" can be made negligible by sufficient amplification of the received signal. Now, in long cables such as those considered in (2), no very great increase in speed of working has been possible by further terminal improvements and it would appear necessary to increase the slope of AB by altering the cable constants. Recent investigations have led to the development of long ocean cables having artificially increased inductance by means of uniform wrappings of "permalloy"—a material which is capable of adding more than 100 milli-henries per naut to the natural inductance of the cable. The added inductance alters the shape of the arrival curve shown in Fig. **1** to the type shown in Fig. **4** and it will be seen that the current is now propagated with a vertical head FO; the shorter the length of cable considered the greater is the height FO, and AB is, theoretically, a vertical line.

In practice AB is not quite vertical, but slopes like A^1B^1 due to variation of the electrical constants with frequency and current.

By reference to Fig. **4** it is quite clear that the time OD is not easily determined by this method. This time, however, will be extremely small and the theoretical speed is enormously higher than the actual speed obtained in any given case, due to the limitations imposed by the irregular causes (*b*).

APPENDIX I.

ARRIVAL CURVES.

Finite Line.

The full line curve in Fig. **1** can be calculated from the Kelvin formula,

$$I_R = \frac{V}{Rl}\left\{1 + 2\sum_{m=1}^{m=\infty} e^{-\frac{m^2\pi^2 t}{CRl^2}} \cos m\pi\right\} \text{.......(1)}$$

where

I_R = received current when both ends of the line are put to earth.

t = time in seconds after application of a steady e.m.f. V volts at the sending end.

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† *Documents of the first reunion of the C.C.I. of the Telegraphic Communications at Berlin. Berne, 1927. Vol. 2, p. 3.*

‡ *Journal A.I.E.E., p. 231. 1927.*

l = length of line.
R = conductor resistance in ohms per unit length.
C = capacity in farads per unit length.

For the part of the curve which governs the slope AB in Fig. 1 a sufficiently accurate expression may be derived from (1) by means of the identity,

$$q\sum_{n=-\infty}^{n=+\infty} e^{-\pi(p+nq)^2} = 1 + 2\sum_{m=1}^{m=\infty} e^{-\pi\left(\frac{m}{q}\right)^2} \cos\frac{2m\pi p}{q}$$

where,

$$p = \frac{q}{2} \text{ and } q^2 = \frac{CRl^2}{\pi t}$$

and hence (1) becomes

$$\underline{I_R = 2V\sqrt{\frac{C}{\pi R}} \cdot \frac{e^{-\frac{\phi}{4t}}}{\sqrt{t}}} \qquad \text{.......................(2)}$$

where $\phi = CRl^2$

This expression becomes less accurate as the values of time t taken approach the time at which the current becomes a maximum.

Infinite Line.

It will be noticed that (2) can be derived from a study of the infinite line as follows:—

Consider a smooth line with distributed resistance R and capacity C per unit length. If I denote the current at distance l from the transmitting end and V the corresponding potential, the differential equations are:—

$$\left.\begin{aligned} -\frac{dV}{dl} &= IR \\ -\frac{dI}{dl} &= C\frac{dV}{dt} \end{aligned}\right\} \qquad \text{...............................(3)}$$

From (3) we obtain

$$\frac{d^2I}{dl^2} = CR\frac{dI}{dt} \qquad \text{...................................(4)}$$

Put $p = \frac{d}{dt}$ and $D = \frac{d}{dl}$.

Then,

$$D = \pm\sqrt{pCR}$$

Hence,

$$I = Ae^{\pm l\sqrt{pCR}} \quad \text{where } A = \frac{V}{Z_0}$$

Assuming that a unit e.m.f. is applied to the line terminals, and that the reflected wave is suppressed, we obtain the operational equation for the current, namely,

$$I = \sqrt{\frac{C}{R}} \cdot \sqrt{p} \cdot e^{-\sqrt{\phi p}} \qquad \text{..................(5)}$$

where $\phi = CRl^2$.

Now,

$$\sqrt{\frac{C}{R}} \cdot \sqrt{p} \cdot e^{-2\sqrt{\lambda p}}$$

$$= \sqrt{\frac{C}{R}} \cdot p \cdot \int_0^\infty e^{-pt} \cdot \frac{e^{-\frac{\lambda}{t}}}{\sqrt{\pi t}} \cdot dt \qquad \text{...........(6)}$$

where λ is any positive real parameter.

In equation (6) put $\lambda = \frac{\phi}{4}$ and obtain,

$$\sqrt{\frac{C}{R}} \cdot \sqrt{p} \cdot e^{-\sqrt{\phi p}}$$

$$= \sqrt{\frac{C}{R}} \cdot p \cdot \int_0^\infty e^{-pt} \cdot \frac{e^{-\frac{\phi}{4t}}}{\sqrt{\pi t}} \cdot dt$$

Hence,

$$I_R = \sqrt{\frac{C}{\pi R}} \cdot \frac{e^{-\frac{\phi}{4t}}}{\sqrt{t}} \qquad \text{..........................(7)}$$

If the cable is earthed, or is terminated with a comparatively low resistance, we can assume that the reflection is total and equation (7) must be corrected by the factor 2, therefore, this equation can now be written,

$$\underline{I_R = 2V\sqrt{\frac{C}{\pi R}} \cdot \frac{e^{-\frac{\phi}{4t}}}{\sqrt{t}}}$$

which is the same as equation (2).

Suppose that in addition to the distributed resistance R and capacity C, the cable also has distributed leakance G per unit length. The differential equations are now,

$$\left.\begin{aligned} -\frac{dV}{dl} &= IR \\ -\frac{dI}{dl} &= (G+pC)V \end{aligned}\right\} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Therefore replacing pC by $(pC+G)$ in equation (5) we obtain the operational equation for the current when the leakance is included,

$$I = \sqrt{\frac{C}{R}} \cdot \sqrt{p+\delta} \cdot e^{-\sqrt{\phi p+\psi}} \qquad \ldots\ldots\ldots\ldots(9)$$

$$\text{where } \delta = \frac{G}{C}$$

$$\text{and } \psi = GRl^2$$

Write equation (5) as

$$I_o = \sqrt{\frac{C}{R}} \cdot \sqrt{p} \cdot e^{\sqrt{-\phi p}}$$

$$\therefore\ I_o e^{-\Gamma t} = \sqrt{\frac{C}{R}} \cdot \frac{p}{p+\Gamma} \cdot \sqrt{p+\Gamma} \cdot {}^{-\sqrt{\phi(p+\Gamma)}}$$

where Γ is any positive real parameter.

Now write equation (9) as

$$\begin{aligned} I_g &= \sqrt{\frac{C}{R}} \cdot \frac{p+\Gamma}{p} \cdot \frac{p}{p+\Gamma} \cdot \sqrt{p+\delta} \cdot e^{-\sqrt{\phi p+\psi}} \\ &= \sqrt{\frac{C}{R}} \cdot \left(1+\frac{\Gamma}{p}\right) \cdot \frac{p}{p+\Gamma} \cdot \sqrt{p+\delta} \cdot e^{-\sqrt{\phi p+\psi}} \end{aligned}$$

Hence,

$$I_g = \left(1+\Gamma\int_o^t dt\right) I_o e^{-\Gamma t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(10)$$

Provided

$$\Gamma = \delta = \frac{G}{C}$$

and $\phi\Gamma = \psi = GRl^2$

The value of I_o can be obtained from equation (7), hence, equation (10) can be rewritten

$$I_g = \sqrt{\frac{C}{\pi R}} \cdot e^{-\frac{\phi}{4t}} \cdot \left(\frac{e^{-\Gamma t}}{\sqrt{t}} + \Gamma\int_o^t \frac{e^{-\Gamma t}}{\sqrt{t}} \cdot dt\right) \ldots\ldots(11)$$

The integral term in equation (11) can be evaluated by repeated integration by parts, thus,

$$\int_o^t \frac{e^{-\Gamma t}}{\sqrt{t}} \cdot dt = 2\sqrt{t}\, e^{-\Gamma t}\left\{1+\frac{2\Gamma t}{3}+\frac{4\Gamma^2 t^2}{15}+\ldots\right\}$$

For purposes of calculation equation (11) can now be written,

$$I_g = \sqrt{\frac{C}{\pi R}} \cdot e^{-\frac{\phi}{4t}}\left(\frac{e^{-\Gamma t}}{\sqrt{t}} + 2\sqrt{t} \cdot \Gamma e^{-\Gamma t}\left\{1+\frac{2\Gamma t}{3}+\frac{(2\Gamma t)^2}{15}+\ldots\right\}\right) \ldots\ldots\ldots(12)$$

In equation (7) put $\gamma = \frac{4t}{CRl^2}$, then this equation can now be rewritten as

$$I = \frac{2}{Rl\sqrt{\pi}} \cdot \frac{e^{-\frac{1}{\gamma}}}{\sqrt{\gamma}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

From this equation a curve can be easily drawn to depict the current wave at any distance from the cable terminals. The current, while finite, is negligibly small until γ reaches the value 0.2. In the neighbourhood of this point it begins to build up rapidly, reaching at $\gamma=2$ its maximum value. From equation (12) the effect of the leakance can be easily calculated and interpreted, and it can be seen that the leakance attenuates the wave by the factor $e^{-\frac{G}{C}\cdot t}$ and at the same time adds a progressive integral of the attenuated wave.

APPENDIX II.

SIMILAR SIGNAL SHAPES.

If the series representing I_R in equation (1) of Appendix I. be written in functional form as

I(t), then an elementary signal of time duration T can be expressed in the form

$$D = I(t) - I(t - T) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Expanding this by Taylor's Theorem we get

$$D = T \cdot \frac{dI}{dt} - \frac{T^2}{\underline{|2}} \cdot \frac{d^2I}{dt^2} + \frac{T^3}{\underline{|3}} \cdot \frac{d^3I}{dt^3} - \ldots (2)$$

which becomes, for relatively small values of T,

$$D = T \cdot \frac{dI}{dt} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

corresponds to the time represented by OD in Fig. 1.

For times less than OD the series expansion of (2) does not converge rapidly and (3) cannot be used with a good degree of approximation.

APPENDIX III.

Loaded Telegraph Cable.

A. Uniform Cable.

The signalling speed will always be limited by the fact that the signals are formed exclusively by the initial "slope" of the arriving current wave, but the addition of effective inductance to the line, by giving to the current wave an initial steep "head" reduces the importance of this factor.

If I denotes the current and V the voltage at any point l on the line, then, neglecting leakance, the differential equations of the problem are:—

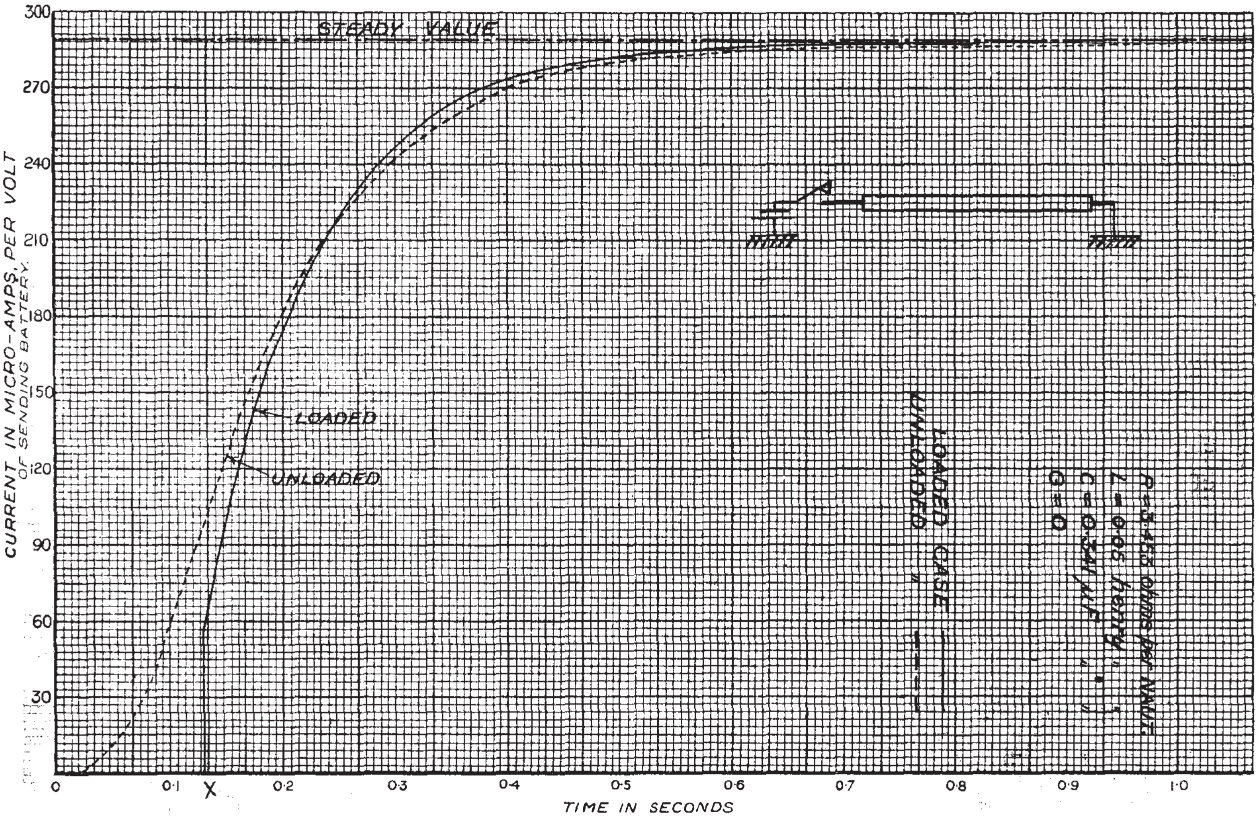


Fig. 6.—Calculated Curves of Arrival for 1,000 Nauts. of Uniform Cable.

It will be found that $\frac{dI}{dt}$ reaches a maximum when $t = 0.09\ \varphi$ where $\phi = CRl^2$, but that from $t = 0.083\ \phi$ to $t = 0.10\ \phi$ the value of $\frac{dI}{dt}$ is relatively constant. Therefore by examination of (3) from the value $t = 0.083\ \phi$ to $t = 0.10\ \phi$ the elementary signal shapes will be essentially similar, having amplitudes proportional to the duration time T and further the value $t = 0.083\ \varphi$

$$\left.\begin{aligned} -\frac{dV}{dl} &= L\frac{dI}{dt} + IR \\ -\frac{dI}{dl} &= C\frac{dV}{dt} \end{aligned}\right\} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

From (1) we obtain the fundamental differential equation for the current wave, viz.,

$$\frac{d^2I}{dl^2} = LC\frac{d^2I}{dt^2} + RC\frac{dI}{dt} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

This equation introduces the phenomenon of true propagation with finite velocity, instead of the diffusion phenomenon of the unloaded line and is more difficult to solve.

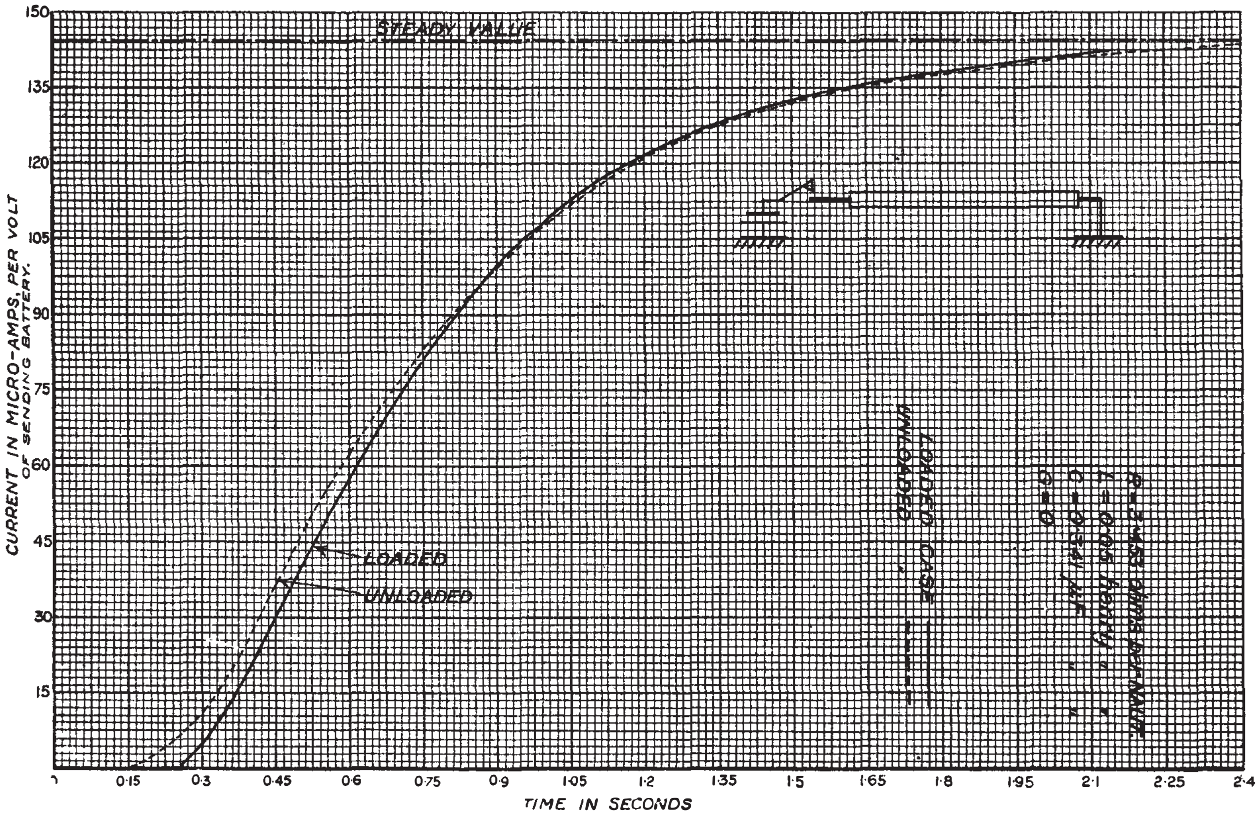


FIG. 7.—CALCULATED CURVES OF ARRIVAL FOR 2,000 NAUTS. OF UNIFORM CABLE.

In equation (2) put $p = \frac{d}{dt}$ and $D = \frac{d}{dl}$, then

$$D = \pm\sqrt{pC(pL + R)} = \pm\gamma$$

Hence,

$$I = Ae^{\pm\gamma l} \text{ where } A = \frac{E}{Z_0}$$

Assuming that a unit e.m.f. is applied to the line terminals and that the reflected wave is suppressed, we have,

$$I = \frac{pC}{\gamma}e^{-\gamma l} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$\text{where } \gamma = \frac{1}{a}\sqrt{p^2 + 2\phi p}$$

$$a^2 = \frac{1}{LC}$$

$$\phi = \frac{R}{2L}$$

Hence,

$$I = \sqrt{\frac{C}{L}} \cdot p \cdot \frac{e^{-\frac{l}{a}\sqrt{p^2+2\phi p}}}{\sqrt{p^2 + 2\phi p}}$$

$$= \sqrt{\frac{C}{L}} \cdot p \cdot \int_0^\infty e^{-pt} \cdot F(t)dt \qquad \ldots\ldots\ldots\ldots (4)$$

The problem is thus reduced to evaluating the functions $F(t)$ from the operational equation.

Assume $\lambda = \frac{l}{a} = 2\phi p$, then equation (4) can be written as,

$$I = \sqrt{\frac{C}{L}} \cdot \frac{e^{-\sqrt{p^2+\lambda^2}}}{\sqrt{p^2+\lambda^2}}$$

$$= \sqrt{\frac{C}{L}} \int_{\lambda}^{\infty} e^{-pt} J_0(\lambda\sqrt{t^2-1})dt \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

where the R.H.S. of this equation defines a function which is zero for $t < \lambda$ and has the value $J_0(\sqrt{t^2-\lambda^2})$ for $t > \lambda$, where J_0 represents the Bessel function of order zero.

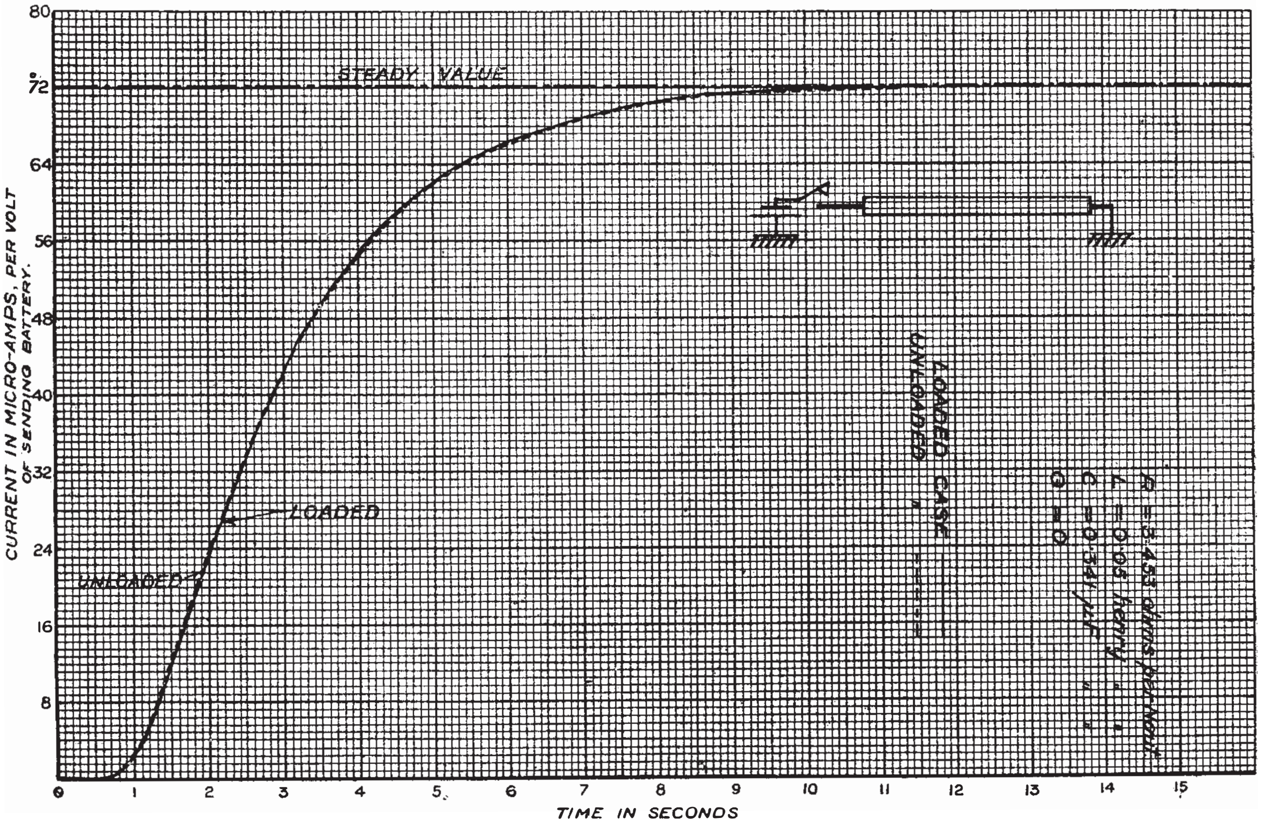


FIG. 8.—CALCULATED CURVES OF ARRIVAL FOR 4,000 NAUTS. OF UNIFORM CABLE.

Now assume that p increases by a value h, equation (5) can now be rewritten as

$$\sqrt{\frac{C}{L}} \cdot \frac{e^{-\frac{l}{a}\sqrt{(p+h_1)^2+\lambda_1^2}}}{\sqrt{(p+h_1)^2+\lambda_1^2}}$$

$$= \sqrt{\frac{C}{L}} \int_{\frac{l}{a}}^{\infty} e^{-pt-h_1 t} J_0\left(\lambda_1\sqrt{t^2-\frac{l^2}{a^2}}\right)dt \quad \ldots\ldots(6)$$

Where h_1 and λ_1 are arbitrary parameters restricted to positive values,

$$\text{here} \quad \lambda_1 = \frac{a}{l} \cdot \lambda$$

$$\text{and} \quad h_1 = \frac{a}{l} \cdot h$$

Now comparing equation (6) with the operational equation (4) we see that they can be made identical provided we set,

$$h_1 = \phi$$

$$\text{and} \quad \lambda_1 = j\phi \quad \text{where } j = \sqrt{-1}$$

Thus equation (4) now becomes

$$\sqrt{\frac{C}{L}} \cdot \frac{e^{-\frac{l}{a}\sqrt{p^2+2\phi p}}}{\sqrt{p^2+2\phi p}}$$

$$= \sqrt{\frac{C}{L}} \int_{\frac{l}{a}}^{\infty} e^{-pt-\phi t}\, I_0\left(\phi\sqrt{t^2-\frac{l^2}{a^2}}\right) dt \quad \ldots\ldots\ldots\ldots(7)$$

Hence,

$$I=\sqrt{\frac{C}{L}}\cdot e^{-\phi t}\cdot I_0\left(\phi\sqrt{t^2-\frac{l^2}{a^2}}\right)\ \ldots\ldots\ldots(8)$$

where $I_0=J_0(jx)$ is a Bessel function of imaginary argument, the value of which can be obtained from tables.

Effect of Leakance.

In order to obtain the operational equation for the current when the distributed leakance G is included, replace pC by $(pC+G)$ in equation (3) and obtain,

$$I=\frac{(pC+G)}{\gamma}\ e^{-\gamma l}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

Where

$$\gamma^2=(Lp+R)\ (Cp+G)$$

$$=\frac{1}{a^2}\left[(p+\phi_1)^2-\phi_2{}^2\right]$$

$$\text{where}\quad a^2=\frac{1}{LC}$$

$$\phi_1=\frac{R}{2L}+\frac{G}{2C}$$

$$\phi_2=\frac{R}{2L}-\frac{G}{2C}$$

Hence,

$$I=a\left(C+\frac{G}{p}\right)\cdot p\cdot\frac{e^{-\frac{l}{a}\sqrt{(p+\phi_1)^2-\phi_2{}^2}}}{\sqrt{(p+\phi_1)^2-\phi_2{}^2}}$$

$$=\sqrt{\frac{C}{L}}\cdot F_1(t)+\frac{G}{\sqrt{LC}}\int_0^t F_1(t)dt\ \ldots\ldots(10)$$

To evaluate the function $F_1(t)$, use equation (6) and put

$$h_1=\phi_1$$
$$\text{and}\quad \lambda_1=\phi_2$$

Then equation (10) can be rewritten as

$$I=\sqrt{\frac{C}{L}}\cdot e^{-\phi_1 t}\ I_0\left(\phi_2\sqrt{t^2-\frac{l^2}{a^2}}\right)$$

$$+\frac{G}{\sqrt{LC}}\int_{\frac{l}{a}}^{t} e^{-\phi_1 t}\ I_0\left(\phi_2\sqrt{t^2-\frac{l^2}{a^2}}\right)dt\ \ldots\ldots(11)$$

$$\text{for } t>\frac{l}{a}$$

Equation (11) is an exact formula for the current wave in terms of Bessel functions and in order to evaluate the definite integral it is necessary to expand the Bessel function as a power series, integrate term by term and rearrange. Thus it is a matter of considerable labour to determine the effect of the leakance for any particular case.

Consider a point l on the cable, the current is zero until $l=at$, at which time it jumps suddenly to the value,

$$I_c=\sqrt{\frac{C}{L}}\cdot e^{-\frac{\phi_1 l}{a}}.$$

After this initial jump the current may attain a maximum value which is large compared with the " head " of the wave, and the resulting curve given by equation (11) is of the type indicated in Fig. **4.**

Equation (3) is based on the assumption that the reflected wave is suppressed, but if the impedance of the terminal apparatus is very small the reflection may be regarded as total, *i.e.,* the current is doubled and consequently equation (3) must be corrected by the factor 2. As the length l is increased, or the value of the added L is decreased, the " head " of the wave becomes smaller and if l be increased beyond a certain limit (or the value of L added is too small to be effective) then the resulting curve approaches coincidence with the dotted unloaded curve shown in Fig. **4.** See Figs. **9, 10** and **11.**

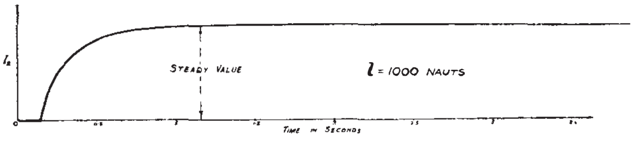


Fig 9

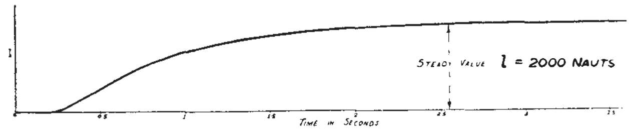


Fig. 10.

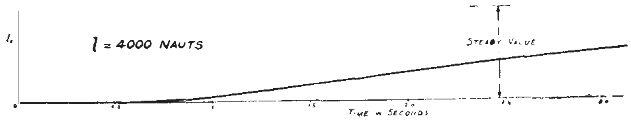


Fig. 11.

B. *Artificial Network with Loading.*

To study the effect of inductance on the arrival curve the cable can be replaced by a meshwork and the number of meshes increased until it behaves practically as a cable having the same total values of L, R and C uniformly distributed throughout its length. Such an artificial cable has been constructed at the laboratories at Dollis Hill and contains 1,050 meshes. These meshes have the values shown in Fig. **5** and is such that when all the meshes are in series it represents an actual cable having a length of 4,000 nauts. with the following constants:—

R = 3.45 ohms per naut.
C = 0.34 μF. ,, ,,
L = 0.05 henry ,, ,,

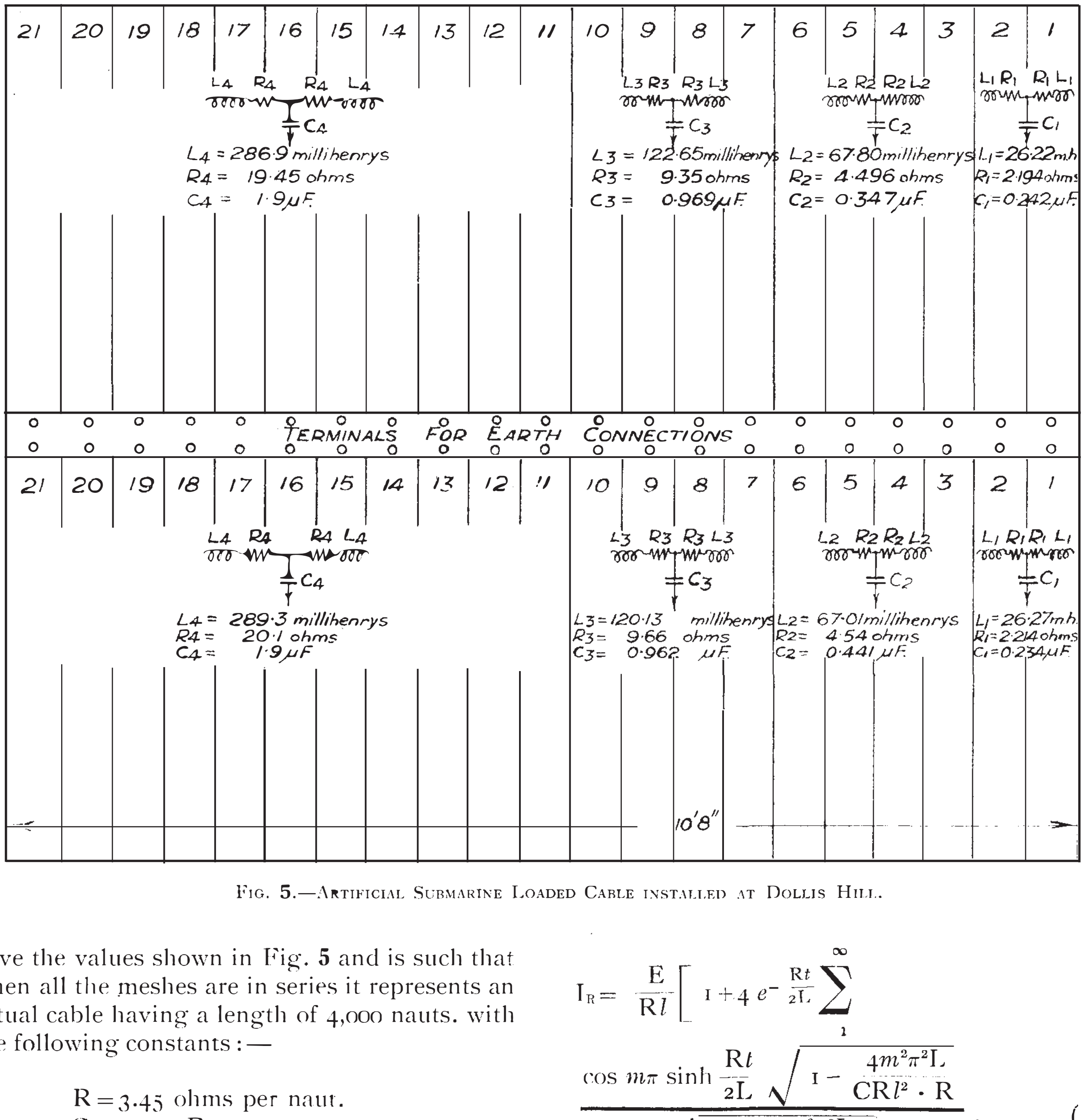


FIG. **5**.—ARTIFICIAL SUBMARINE LOADED CABLE INSTALLED AT DOLLIS HILL.

By the use of Heaviside's Expansion Theorem the series given in equation (1), Appendix I., can be deduced by calculating the arrival current for the *n*th section of an artificial network and passing to the actual case of a cable by putting $n = \infty$. Following this procedure Dr. Malcolm proves that when inductance is added to the cable equation (1), Appendix I., can be replaced without serious error by:—

$$I_R = \frac{E}{Rl}\left[1 + 4e^{-\frac{Rt}{2L}} \sum_{1}^{\infty} \frac{\cos m\pi \sinh \frac{Rt}{2L} \sqrt{1 - \frac{4m^2\pi^2 L}{CRl^2 \cdot R}}}{\sqrt{1 - \frac{4m^2\pi^2 L}{CRl^2 \cdot R}}} \right. \qquad \ldots\ldots\ldots\ldots(12)$$

and this applies after the time t_c seconds where

$$t_c = l\sqrt{LC} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

Before this time the current $I_R = 0$ and at t_c jumps suddenly to the height of the ordinate given by

$$I_c = \frac{2E}{Z_0} \times e^{-\beta l} \doteqdot 2E\sqrt{\frac{C}{L}} \cdot e^{-\frac{Rl}{2}\sqrt{\frac{C}{L}}} \ldots\ldots\ldots(14)$$

where Z_0 = the characteristic impedance, β = attenuation constant.

Equations (12), (13) and (14) just given can be used to replace equation (8) for calculation purposes. Curves in Figs. **6**, **7** and **8** have been so calculated for the lengths of cable indicated, whilst in Figs. **9**, **10** and **11** are reproduced the actual corresponding arrival curves. The agreement between the actual curves and the calculated curves is very good and the wave-front for $l = 1000$ nauts. departs from the vertical slightly due to the variation of the inductance and resistance units of the network with frequency and current.

From the foregoing results, as the length l is increased, it can be clearly seen how the effective value of the inductance decreases until at $l = 4000$ nauts. the arrival curve is practically coincident with the unloaded curve, although the actual value of inductance (0.05 henry per naut.) is much greater than the natural inductances of such a cable.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

TELEPHONES AND WIRE MILEAGES, THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 30TH JUNE, 1928.

No. of Telephones owned and maintained by the Post Office.	Overhead Wire Mileages.				Engineering District	Underground Wire Mileages.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
588,706	537	4,036	51,577	170	London	24,198	68,040	2,251,365	106,942
75,696	2,169	21,547	64,814	1,575	S. East	3,989	46,411	189,535	33,902
79,079	4,538	30,737	55,228	2,913	S. West	20,359	11,651	143,156	60,387
61,864	6,077	37,508	58,556	5,030	Eastern	23,167	37,176	108,340	71,609
76,861	8,586	44,919	58,146	3,895	N. Mid.	27,896	53,288	241,400	115,817
95,371	4,682	29,491	70,982	4,577	S. Mid.	12,008	22,671	179,874	88,481
57,373	4,385	29,606	51,806	3,136	S. Wales	6,277	26,084	118,322	71,934
102,443	8,185	26,237	49,262	4,213	N. Wales	13,393	41,104	267,926	61,004
156,403	1,495	16,450	43,186	2,439	S. Lancs.	13,149	78,189	464,817	48,912
91,836	6,164	30,746	46,755	3,144	N. East	11,609	45,487	220,456	66,535
63,392	4,105	24,762	37,641	2,408	N. West	8.053	33,116	161,300	36,834
46,614	2,511	16,135	25,009	2,542	Northern	4,697	14,915	107,194	50,866
21,107	4,564	8,343	13,905	554	Ireland N.	131	2,322	38,190	1,579
64,591	5,441	25,567	37,222	1,467	Scot. East	3,776	12,851	147,923	47,556
86,762	7,329	24,243	42,972	888	Scot. West	12,133	24,549	219,857	34,673
1,668,098	70,768	370,327	707,061	38,951	Total	184,835	517,854	4,859,655	897,031
1,639,837	70,509	368,939	697,790	36,915	Figures as 31st March, 1928.	180,552	507,932	4,719,708	880,678

MEASUREMENT OF IMPULSE RATIO AND FREQUENCY IN AUTOMATIC NETWORKS.

C. L. Hosking and R. M. Badenach, B.Sc.

(Postmaster-General's Department, Australia.)

To ensure reliable operation of an automatic exchange, it is essential that the characteristics of all the impulses delivered into that exchange, either from subscribers' lines or over junction lines from other automatic exchanges, shall be such that correct operation of the switches will result. In a network where the majority of impulses are generated by a dial at the subscribers' premises, the features in which the impulse is most likely to be unstandard are (1) ratio and (2) frequency, the former being the more important.

Frequency errors can only arise at the dial, but the factors causing distortion of impulse ratio are legion. In a multi-office network, such as Melbourne or Sydney where the conversion to automatic working was commenced in 1913 and is still proceeding, these factors may be summarised as follows:—

(*a*) Variations in the dials in use due to manufacturing differences and standards and to incorrect adjustment. In addition to the dials supplied in 1913 there are in use numerous other types supplied by various manufacturers since that date.

(*b*) Varying dialling circuits in substation equipment. The earlier substation sets are of the series receiver type and the dial is not shunted whilst impulsing, but later types are fitted with induction coils and the condenser is introduced into the dialling circuit. These types again vary in the actual circuit conditions during dialling. Further variations occur due to P.B.X., extension, parallel sets and other special services.

(*c*) Varying lines conditions. Nominally the networks extend for a radial distance of 10 miles from the central exchanges of the areas but in practice there are suburban exchanges beyond this limit. In addition, several exchanges on the limits of the areas are comparatively large, so the distortion of impulses due to long junction lines is obvious. It might be mentioned here in passing that it has been noticed that the insulation resistance of a line that tests satisfactorily on the test desk voltmeter fails apparently under the stress of dialling voltages and so distorts the impulses by having a shunting effect on the impulsing relay.

(*d*) Repeating impulses between exchanges. A call from one branch exchange to another branch may pass through three repeaters.

(*e*) Variations in the resistance and mechanical and electrical adjustment of impulsing relays. There are at least four types in use, the equipment containing the relays having either been supplied by different manufacturers or at various periods by one manufacturer.

(*f*) The standard of switch adjustment for any particular exchange is the interrupter or varying machine, and manufacturers for complete exchange installations have from time to time supplied machines the characteristics of which differ. It would appear, however, that these alterations compensate to some extent for the variations mentioned in (*e*).

(*g*) Unstandard frequency of impulses. The ratio of " make " to " break " of an " A " relay in the train of switches depends upon the frequency at which it is impulsing.

Although the factors mentioned above individually may not cause switch failure, the cumulative effect is sufficiently great to cause considerable trouble, and experience has shown the necessity of having some simple and reliable means of effecting any necessary corrections.

As mentioned under (*f*) above, the group and final selectors in any automatic exchange are subjected to frequent routines by means of an interrupter or varying machine. This machine delivers impulses of a definite ratio and speed under conditions which represent two extreme conditions of dialling. These conditions are:—

(*a*) With a maximum resistance in series with the impulsing relay under test. In this case the impulsing spring of " A " relays on selectors remains on the back contact for a comparatively long period, resulting in a " heavy impulse " being transmitted to the operating magnets. The switch would in such circumstances tend to fail due to the relapse of the " B " relay;

(*b*) With a minimum resistance shunted across the impulsing relay. Under this test the " A " relay tends to remain energised and consequently a " light impulse " is transmitted, the switch tending to fail on account of the operating magnets being insufficiently energised or the relapse of the " C " relay.

It is considered that all impulses received in a particular exchange should fall within these limits. The problem is, however, to obtain a means of defining these limits in such a manner that any impulse can be checked readily. The natural location for checking the condition of a subscriber's service is the test desk, and the instrument that naturally suggests itself for use is the ordinary test desk voltmeter. It was keeping these factors in mind that the test circuit indicated in Fig. 1 was developed.

The operation is as follows:—By throwing test key K^1 the circuit under test is connected to relay " A " which is energised. On the first break of the dial impulse springs the short-circuit is removed from " C," which operates and remains operated during the train of impulses, owing to the slugging effect due to its winding being short-circuited. " B " is adjusted to remain energised for more than 0.9 seconds but for less than 1 second. Contacts B^1 and C^1 being closed, the impulsing of A^1 is transmitted to the low scale winding of the voltmeter.

It will be noted that the negative terminal of the voltmeter is permanently connected to the junction of resistances X and Y and that the other terminal is alternately at a higher and lower potential compared with the negative terminal depending upon the impulsing of A^1.

Owing to the inertia of the moving system of the voltmeter, the needle takes up a position depending upon the proportion of impulse time that the impulsing contact of relay " A " is making on the front or back contact. This reading is therefore in essence a measure of impulse ratio.

Relay " A " should be the same type of impulse relay as used in the selector switches in the exchange, and should be adjusted to the manufacturer's standard. Relay " B " serves to disconnect the voltmeter just prior to the completion of a train of impulses, and so prevents an unnecessarily long final deflection due to the slow release of " C." Relay " C " controls " B," and contact C_1 prevents deflections when " B " is operated prior to the reception of dialling impulses or between trains of impulses.

To calibrate the test circuit the exchange interrupter machine is carefully adjusted to give 10 impulses per second and is connected to the test circuit so as to cause relay " A " to impulse continuously. Relay " B " of the test circuit is permanently wedged up so that the continuous train of impulses is indicated on the voltmeter. The " loop " key on the interrupter machine is operated and the voltmeter should be so connected and the resistance of X and Y so adjusted that under these conditions the needle takes up a position approximately 7 divisions on the right of the zero. On the operation of the " shunt " key the needle moves to the left of zero. These tests are repeated until a deflection of 7 divisions is obtained on either side of zero. A higher reading than the figure mentioned is not advisable, otherwise during testing the instrument pointer will take too long to reach a final position.

The voltmeter scale is permanently amended as indicated in Fig. **2**. Here only five divisions are shown on either side of zero. The instrument is calibrated for a deflection of 7 divisions as explained earlier, but in order to obtain a margin of safety all impulsing devices are adjusted so that the reading falls within 5 divisions in either direction from zero. Impulses which show beyond the limit in the direction of the normal scale of the voltmeter are called " heavy," and the impulsing springs of the dial under test are suitably adjusted to bring the reading within the limits. Readings beyond the limit below zero are termed " light," and here again in most cases suitable adjustment can be obtained by slightly altering the spacing of the dial impulsing springs. Care is exercised, however, to ensure that these adjustments are not carried beyond the limits of safe mechanical operation. Provided a dial is adjusted to the correct ratio before installation, tests taken recently indicate that on new services it should only be for special circuits such as extension working, parallel services, P.B.X. circuits, etc., that an adjustment for impulse ratio is necessary. The test, however, should be applied as a matter of routine whenever a subscriber's service is being inspected by the maintenance force.

The test circuit has been used to great advantage for repeater adjustment between exchanges, but to date the limits of its usefulness in this direction have not been fully exploited.

It is realised that the circuit is not perfect. Tests are being conducted at present to improve the method of calibration, particularly in the direction of defining the limits and the margin of safety to be allowed. Errors also arise due to the " lost time " of contact of a dialling relay and to variation of exchange voltage. It is considered, however, the accuracy obtained is well within the limits procurable for any electrical measurement on an exchange test desk. The circuit is installed in several exchanges and its

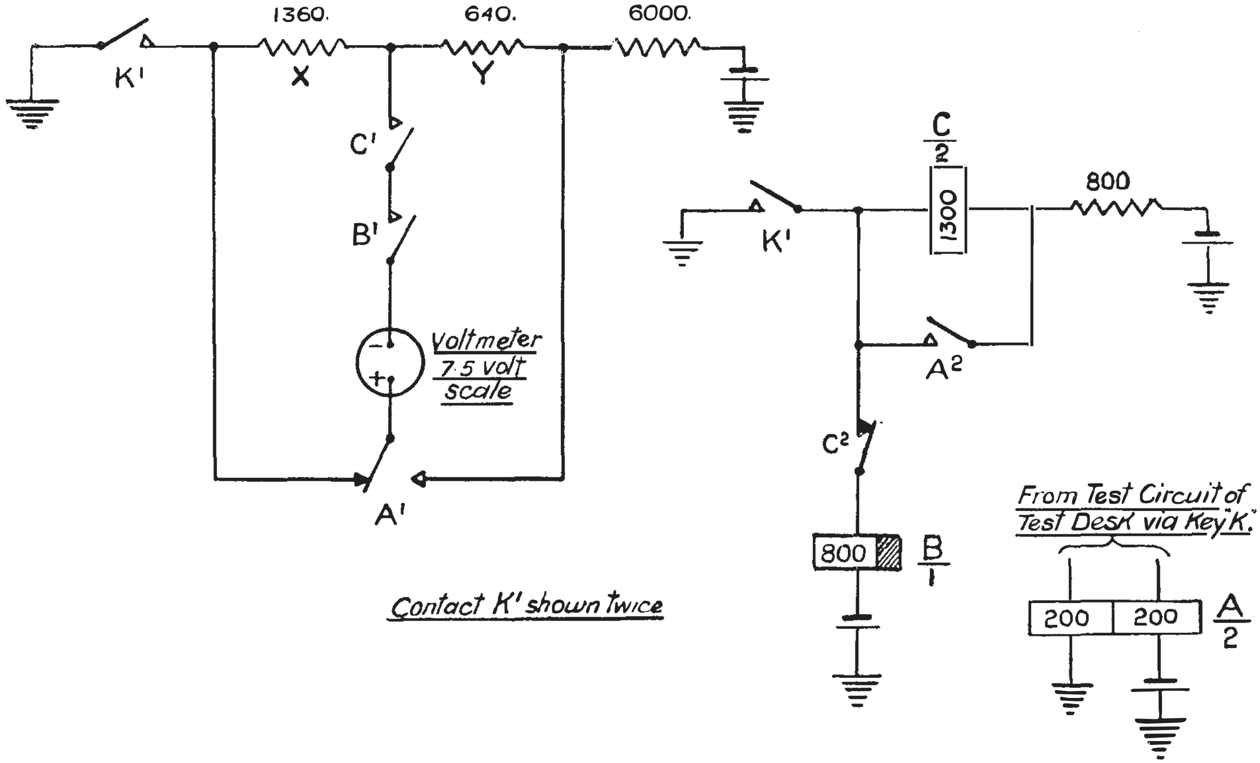
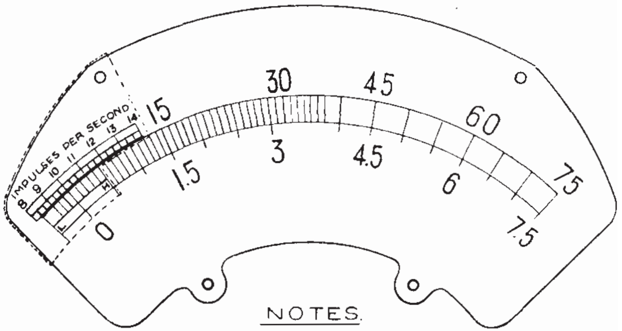


Fig. **1**.—Circuit for Measuring Ratio of Impulse.



NOTES.
Additional Scale enclosed by dotted lines
Letters L & H indicate margins of scale used for Weight test. L denotes Light. H denotes Heavy Upper figures indicate Impulse frequency.

FIG. 2.—VOLTMETER SCALE MODIFIED FOR TESTING IMPULSE FREQUENCIES AND WEIGHT.

usefulness and accuracy has been well proved. The circuit shown in Fig. 1 is schematic only and does not show all the details necessary for connecting the apparatus in the desk test circuit.

An electrical method employing the test desk voltmeter for the measurement of impulse frequency has also been developed, the elements of the circuit being indicated in Fig. 3. The impulsing and voltmeter control relays have not been shown, but this part of the circuit is similar to the corresponding part of Fig. 1, relays AA′, BA′ and CA′ corresponding respectively with relays A, B and C. The test key KA′ is inserted in the regular test circuit on the test desk and, on being thrown, relay AA′ is operated from the subscriber's service under test. The mechanic at the subscriber's premises pulls O on the dial, thus causing relay AA′ to impulse. The impulsing of contact AA′ causes the charge and discharge of the two microfarad condensers, the discharge being dissipated in the closed circuit provided, the charge being obtained through the bridge combination.

The bridge is arranged so that when impulses are being delivered at the rate of 10 per second there is no average potential difference across the terminals of the voltmeter. For frequencies other than 10, an unbalanced condition is set up, a deflection in one direction being obtained on the instrument for frequencies above 10 and in the opposite direction for frequencies below 10.

Owing to the time of charge and discharge of the condensers being small compared with the time of contact of the relay for ordinary impulse frequencies and ratios, the average charging current taken over the time of one impulse train is practically proportional to the frequency of impulsing. Owing to the damping of the voltmeter movement, the pointer takes up an almost stationary position proportional to the average current passing through it, and the instrument may therefore be calibrated to measure frequency.

The frequency is indicated in the manner shown in the top auxiliary scale in Fig. 2. It will be noted that standard speed corresponds with zero deflection. As a dial in standard adjustment takes but one second to deliver its impulses, it is essential that the voltmeter needle move as little distance as possible. Incidentally, it may be mentioned that the sensitivity of the apparatus is such that variations of frequency during a train of 10 impulses are indicated.

To calibrate the circuit, connect the interrupter machine on zero loop to relay AA′. By running the machine alternately at 10 and 14 impulses per second and adjusting resistance *a*, and perhaps *b*, the correct frequency indication can be obtained on the voltmeter. The resistance values shown in Fig. 3 are typical only. Other frequencies should be indicated correctly, but should be checked.

As stated earlier, the keys for connecting both the frequency and ratio test circuits are placed in the ordinary test desk circuit. This arrangement gives a very convenient and rapid method of carrying out the tests, with the added advantage of utilising standard test desk equipment.

Our thanks are due to the Chief Electrical Engineer for permission to use the information gained from various tests.

[*Note.—In the B.P.O. Administration, maintenance men do not adjust faulty dials, but change them on instructions from the Test Clerk. Adjustment of the dials is done by skilled staff at the exchange as a bench job.*—EDS., *P.O.E.E.J.*]

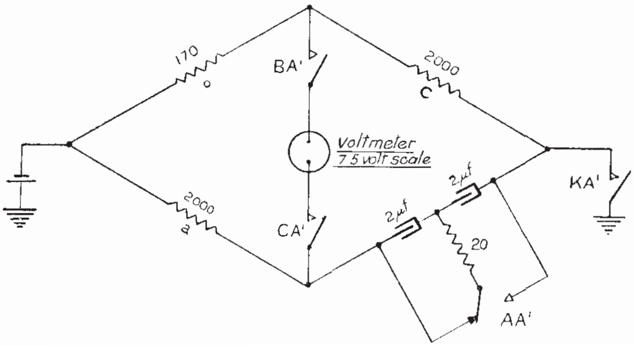


FIG. 3.—IMPULSE FREQUENCY TEST CIRCUIT.

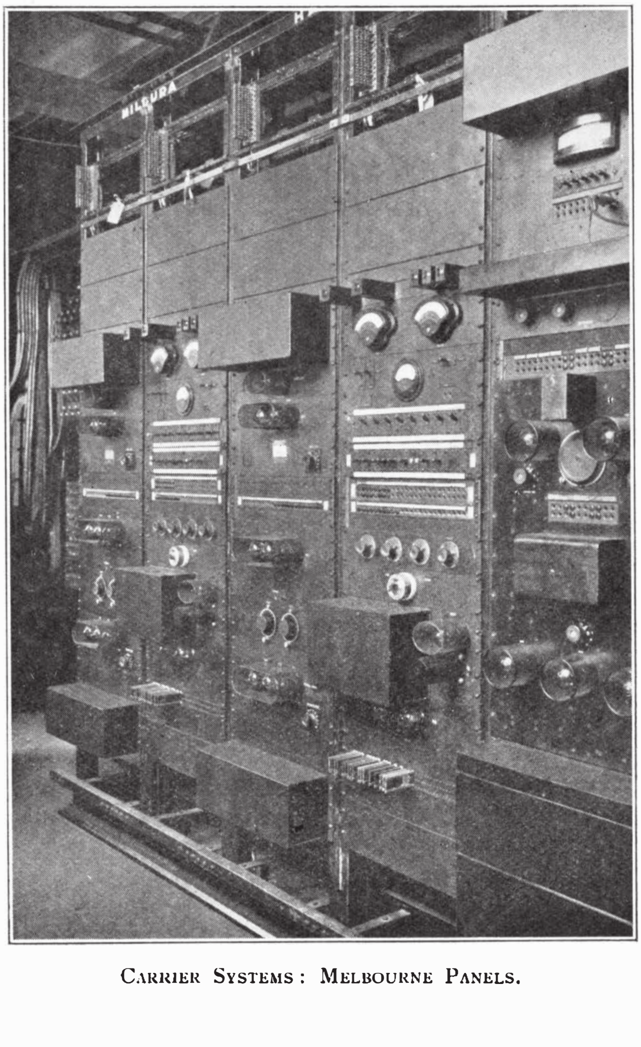
AUSTRALIAN CARRIER SYSTEMS.

INSTALLATION OF SINGLE CHANNEL CARRIER SYSTEM CONNECTING MELBOURNE TO HAMILTON AND MILDURA.

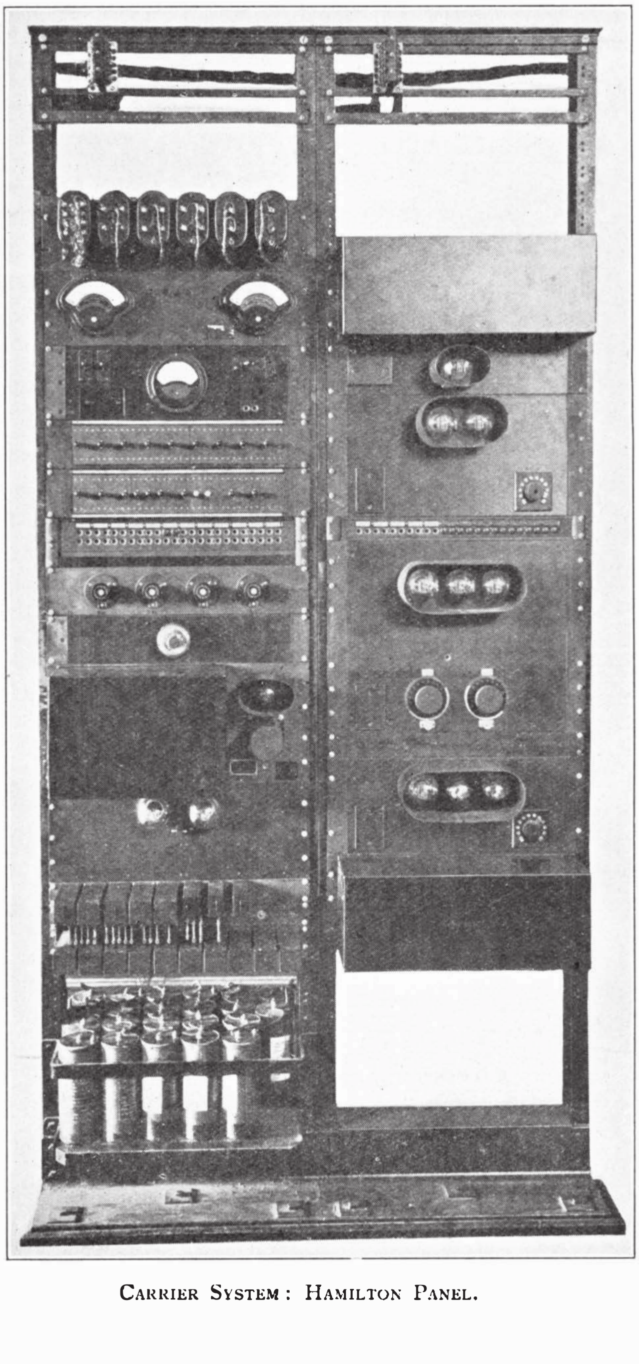
[*From the general data communicated by the Standard Telephones and Cables Company Limited, the officers of the Engineering Branch of the Postmaster-General's Department proposed a scheme whereby the new type of carrier apparatus which had just emerged from laboratory tests should be put into commercial practice. As this equipment is the first of its kind to be installed, it is considered that a brief outline of the system will be of general interest.*]

R. N. Partington, M.I.E. (*Aust.*),
Superintending Engineer, Postmaster-General's Department, for the State of Victoria, Australia.

TYPE C2,F. carrier telephone system was recently developed by the Laboratories of the Standard Telephones and Cables Company Limited, in order to provide economically for a one 2-way telephone channel over a pair of open wire aerial conductors without disturbing any existing facility, either telephone or telegraph.



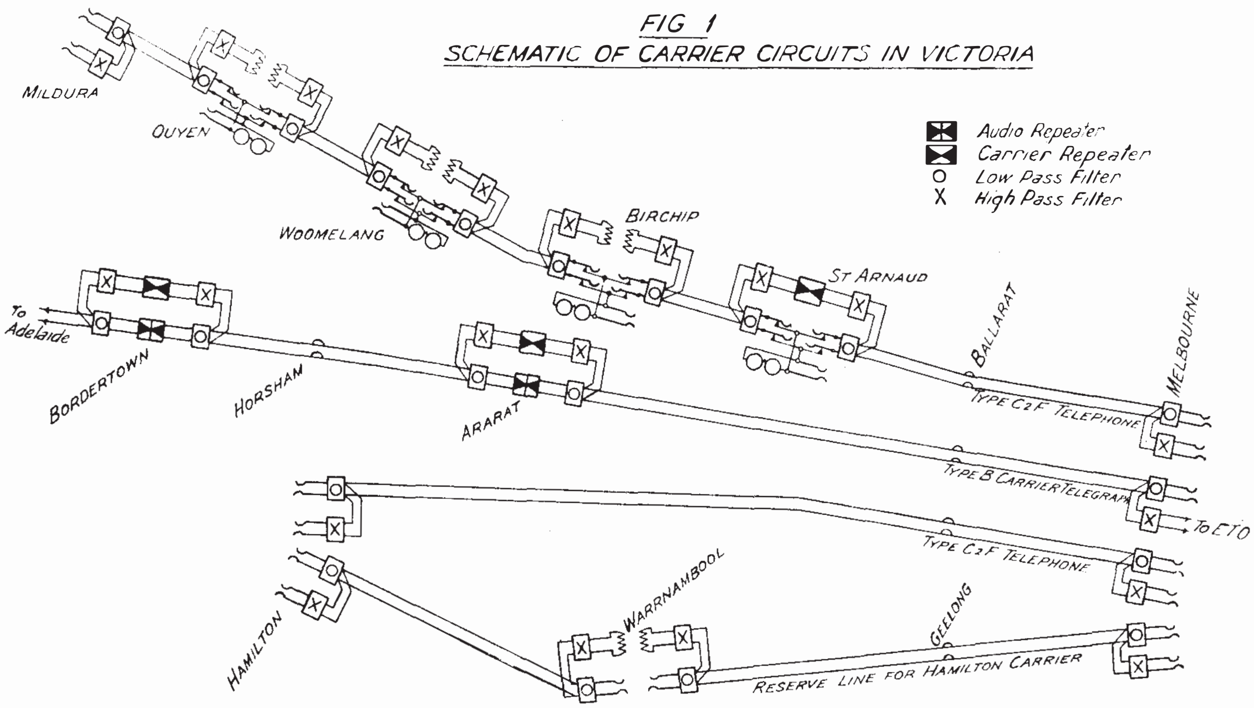
Carrier Systems: Melbourne Panels.



Carrier System: Hamilton Panel.

FIG 1

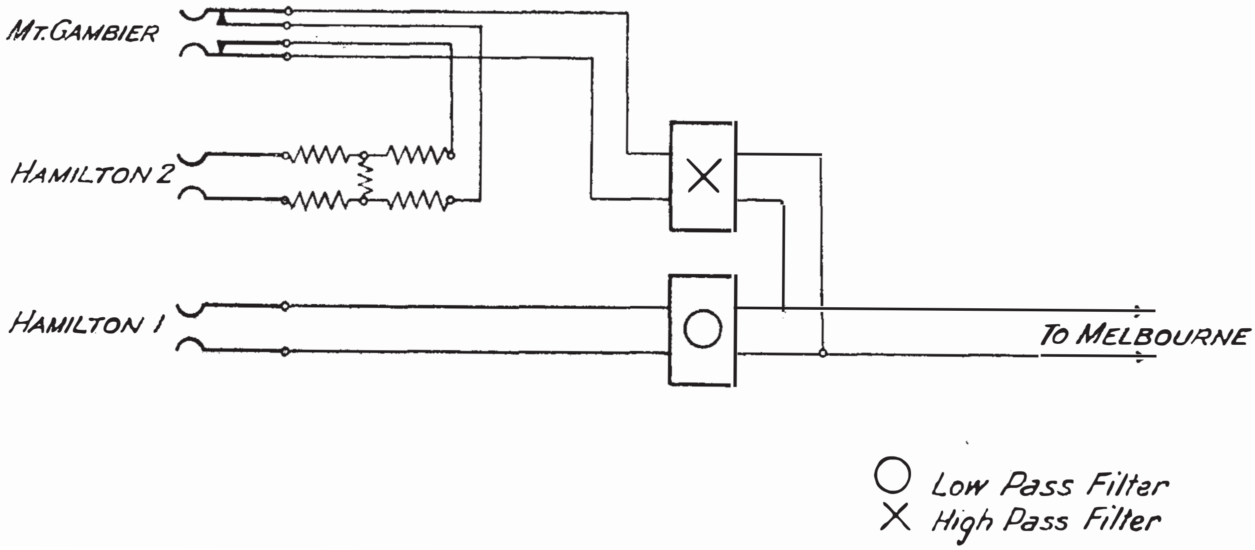
SCHEMATIC OF CARRIER CIRCUITS IN VICTORIA



The system is essentially long haul and is applied in Victoria to connect important country towns separated by a distance between 150 and 800 miles over the route either where relatively few wires exist, or else where congestion would necessitate expenditure on new pole routes. For moderate distances terminal apparatus only is required, but over long ranges it is necessary to have a carrier repeater to compensate for the line losses.

FIG 2

SWITCHING ARRANGEMENTS HAMILTON



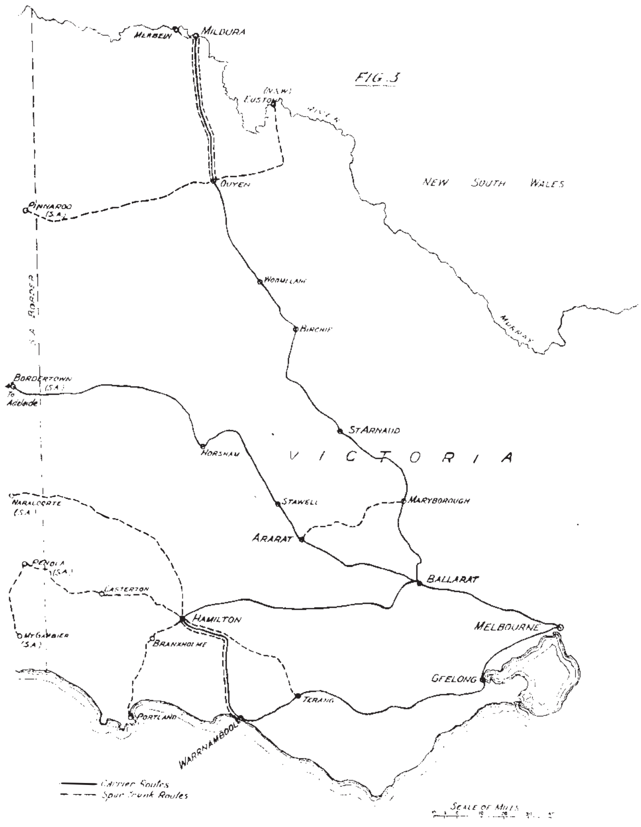


Fig. 3.

The positions of various components of the terminal apparatus are shown in Fig. **4**. On the left is a 4-wire terminating circuit, with which is associated the ringer equipment. Under present practices this is now 16 cycles, but provision has been made to utilise the 1000 cycle ringer. The terminating equipment comprises a hybrid coil and the line balancing network, which function to separate the incoming from the outgoing speech currents. On the extreme right is the carrier line filter group, comprising a high pass filter having a characteristic such that it suppresses currents of frequencies below 3000 cycles, and a low pass filter which suppresses frequencies above 3000 cycles. This group is essential to the derivation of the carrier circuit. The remaining components are shown in greater detail in Fig. **5.**

The current from the carrier oscillator, together with the speech currents from the 4-wire terminating circuit, are together impressed upon the grid of the modulator in such a manner that the modulated carrier current consisting mainly of two side bands and the original speech currents pass through the equaliser which attenuates the lower frequencies of side band more than the upper, so compensating for the unequal propagation in the line and incidentally suppressing the speech current. The transmitting filter, one of two band pass filters connected in parallel across the line, functions to suppress the unwanted modulation component and to transmit the wanted side band, after its power level has been raised to +15 TU by the transmitting amplifier. At Melbourne this filter transmits the lower side band over the carrier line to the receiving filter at the distance

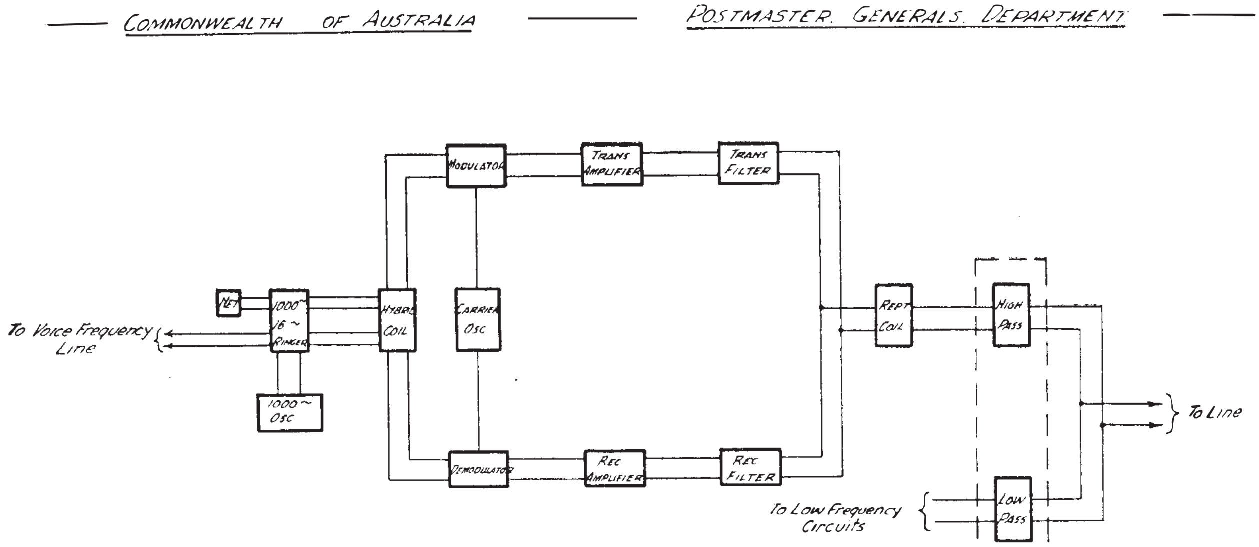


FIG 4

terminal. This attenuated band passes through the receiving amplifier, where its level is raised 12 TU, then to the demodulator which is supplied by the same carrier current as the modulator. Resultant speech currents only are transmitted through the low pass filter to the hybrid coil and thence on to the switchboard.

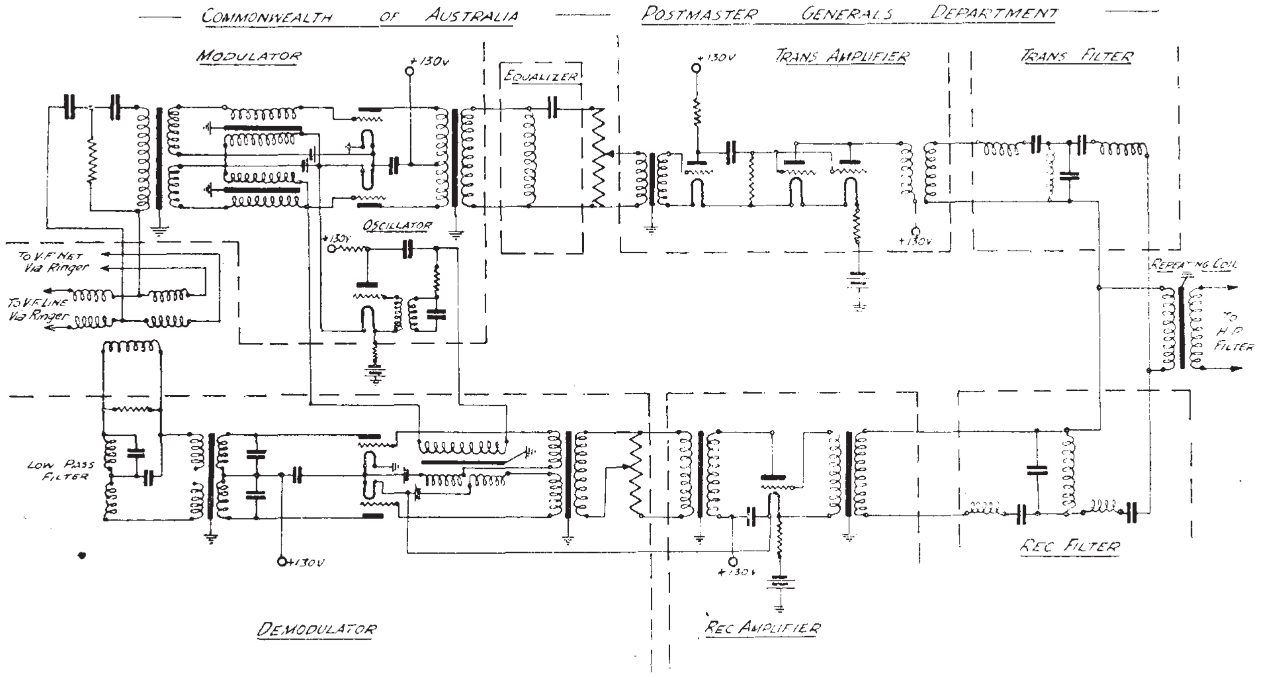


FIG. 5
TERMINAL EQUIPMENT.

The Engineering Department of the Australian Post Office has completed recently the installation of a single channel carrier system between Mebourne and Hamilton in order to improve the transmission over an omnibus circuit between Mt. Gambier and Hamilton. In the western portion of Victoria and the south-eastern portion of South Australia there exists a tremendous farming district having a large community of interest with Melbourne, the capital city of Victoria. Hamilton, a prosperous country town with a population of about 5,000, is situated in the centre of this area and is the logical traffic centre of the telephone and telegraph communication of this district with Melbourne. Prior to the carrier installation, the only means of communication consisted of one 200 lb. H.D.C. non-repeatered open wire line between Melbourne and Hamilton, 168 miles in length, giving an equivalent of approximately 12 TU. In consequence of this voice frequency loss, any feeder line switched at Hamilton over this circuit would have an equivalent in excess of that which the Transmission Section regards as the limit for the propagation of commercial speech. The longest of these spur lines was 100 miles in length and served the famous tourist resort, Mt. Gambier.

The necessity for an improved service with Melbourne caused the Commonwealth Post Office Administration to consider the erection of a direct circuit which would provide good transmission between Mt. Gambier and Melbourne. Both from an economic and transmission standpoint it was decided to instal type C2,F. carrier system between Melbourne and Hamilton, using the existing omnibus line to Mt. Gambier as voice frequency link. To ensure continuity of service a reserve carrier line was obtained on a different pole route by installing carrier transfer filters at Warrnambool.

Fig. 1 is a schematic layout of the carrier lines within that portion of the Commonwealth controlled by the Superintending Engineer for Victoria. The original proposal for the

Melborne-Hamilton circuit required the carrier to operate with a zero equivalent between terminal test boards in order that Mt. Gambier could obtain a 12 TU service. By special engineering devices it was found possible to operate the system at a 4 TU gain on the carrier line and this, together with the 12 TU loss between Hamilton and Mt. Gambier, gave a net equivalent of 8 TU between Melbourne and Mt. Gambier, and, by using one channel of the Melbourne-Sydney system having a 3 TU equivalent, the Administration is able to offer to the telephone public a facility between Mt. Gambier and Sydney, a distance of approximately 1,000 miles, having a voice frequency equivalent of 11 TU. To ensure the carrier system being used to its full advantage, a parallel jack arrangement was installed in the switchboard at Hamilton as shown in Fig. **2**. The 8 TU pad in the voice frequency circuit prevents overloading of the transmitting amplifier, when Hamilton and 4 short spur lines are switched over the system. This pad is automatically cut out when the system is switched through to Mt. Gambier. Considerable trouble was experienced in the provision of a balance network because the nearest office on the voice frequency line between Hamilton and Mt. Gambier was but 2 TU distant. At the Melbourne terminal, only 50 ft. separates the trunk switchboard from the carrier unit and to obtain better balance characteristics a 10 TU pad was inserted permanently in the voice frequency line. This has reduced the possibility of end-to-end sing and undoubtedly the result has made possible the 4 TU gain.

Fig. **3** will enable the reader to picture the area served by these various spur lines and will show that Hamilton is able to switch 4 spur lines extending to Terang Warrnambool, Portland, Mt. Gambier and Narracoorte.

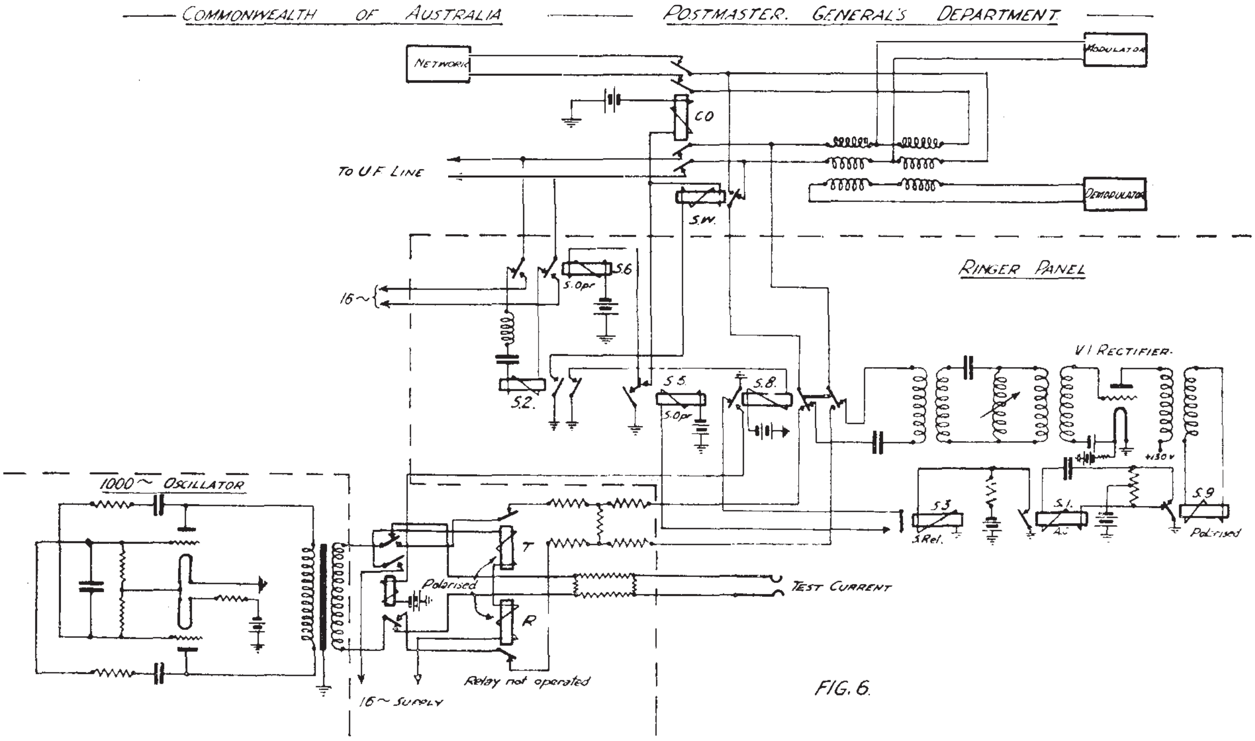


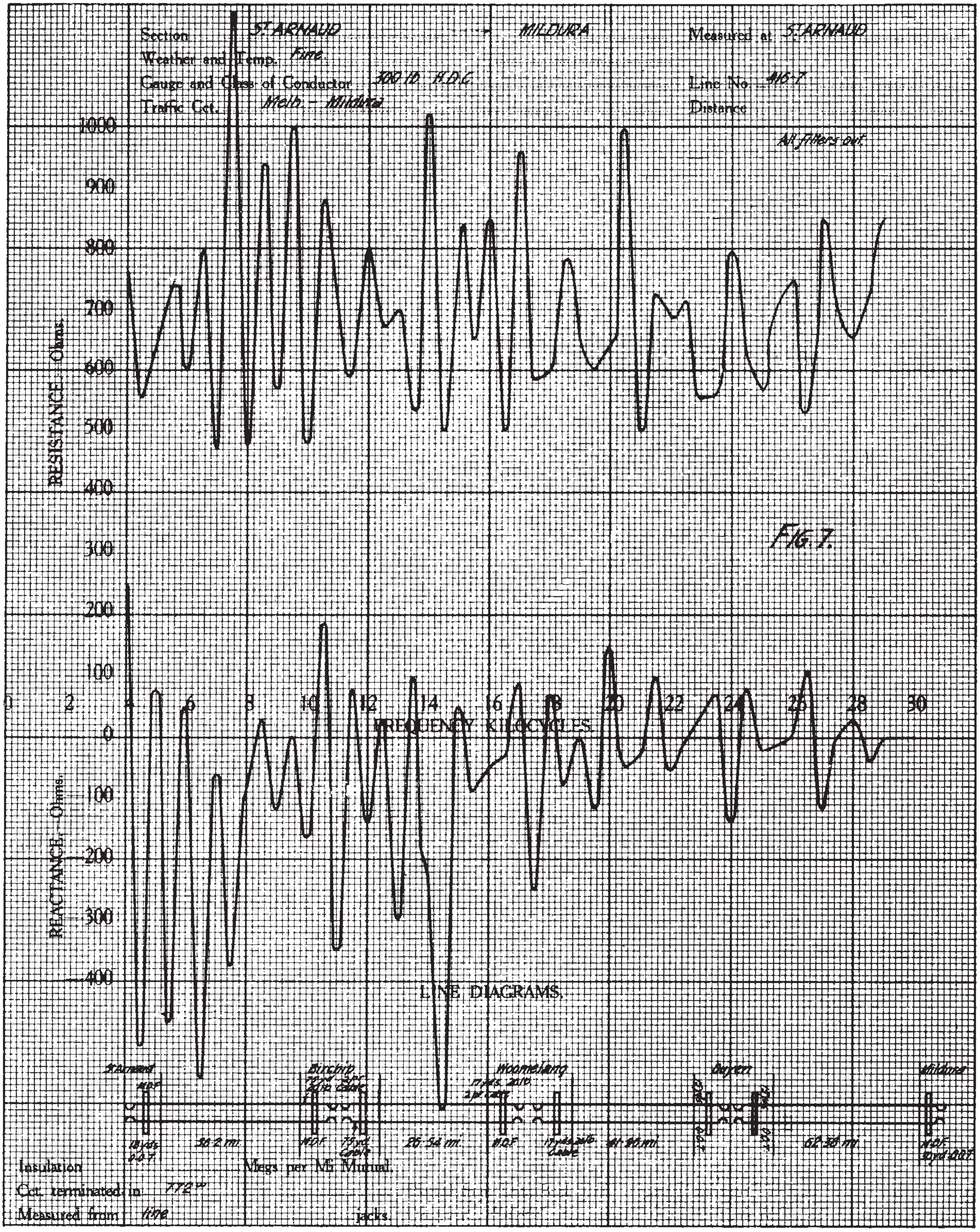
FIG. 6.

1000 Cycle Ringer.

The problem of providing a high grade transmission circuit between Melbourne and Mildura was solved also by the use of a type C2,F. system, together with the installation of an intermediate repeater at St. Arnaud, approximately the half-way point of the line. Mildura is the commercial centre for a district made wealthy and fertile by the successful application of agricultural science to farming problems. It is the centre of a wonderful fruit-growing area, stimulated in recent years

IMPEDANCE v. FREQUENCY CHARACTERISTIC.

T.R.M. 10.



Section St. ARNAUD — MILDURA

Measured at St. ARNAUD

Weather and Temp. Fine.

Gauge and Class of Conductor 300 lb. H.D.C.

Line No. 416-7

Traffic Cct. Melb. – Mildura

Distance

All filters out.

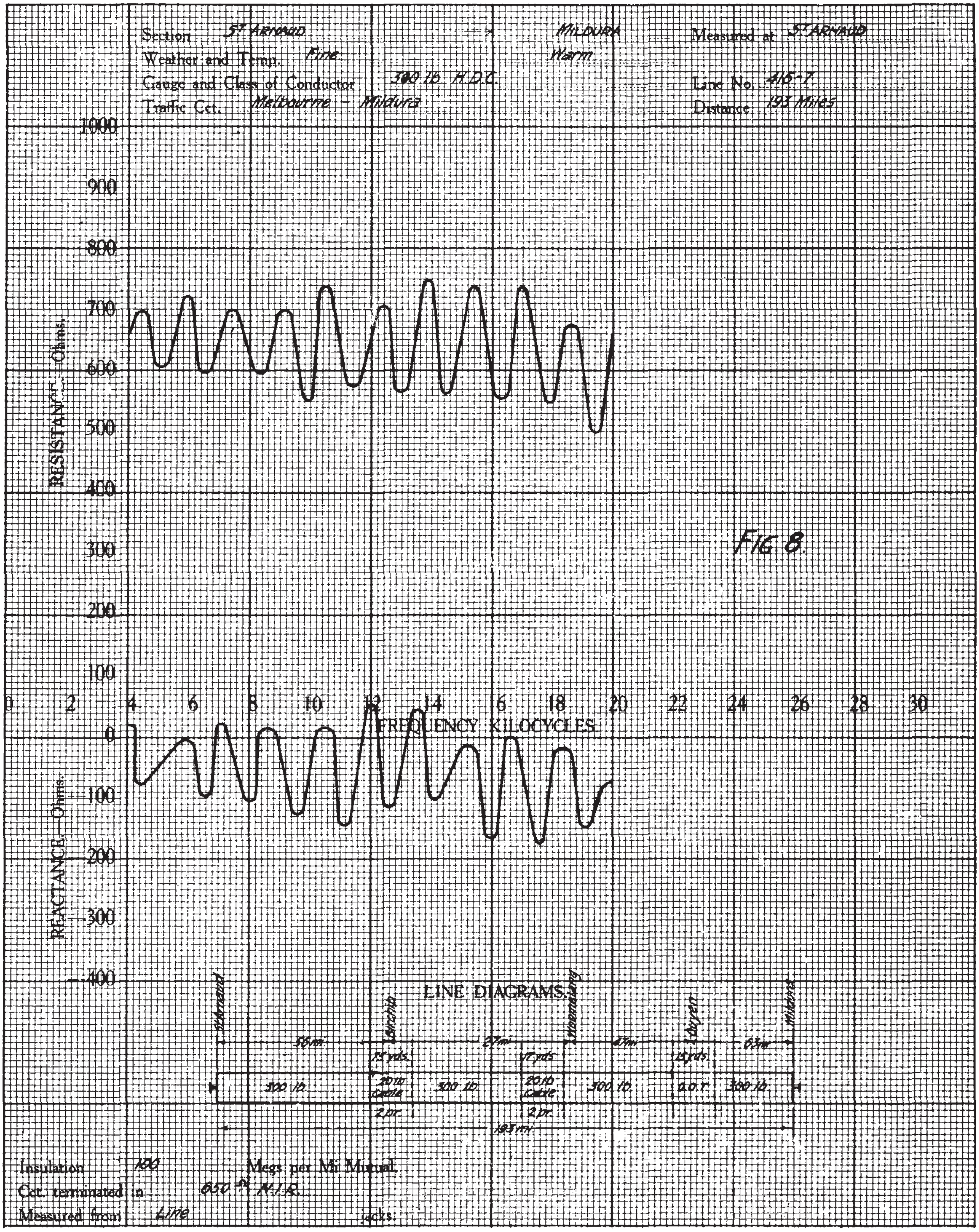
Insulation Megs per Mi Mutual.

Cct. terminated in 772ω

Measured from line jacks.

FIG. 7.

IMPEDANCE v. FREQUENCY CHARACTERISTIC. **T.R.M. 10.**



Section St ARNAUD → MILDURA Measured at St ARNAUD

Weather and Temp. Fine Warm

Gauge and Class of Conductor 300 lb. H.D.C. Line No. 415-7

Traffic Cct. Melbourne - Mildura Distance 193 Miles

Insulation 100 Megs per Mi Mutual.

Cct. terminated in 650 Ω N.I.R.

Measured from Line jacks.

FIG. 8.

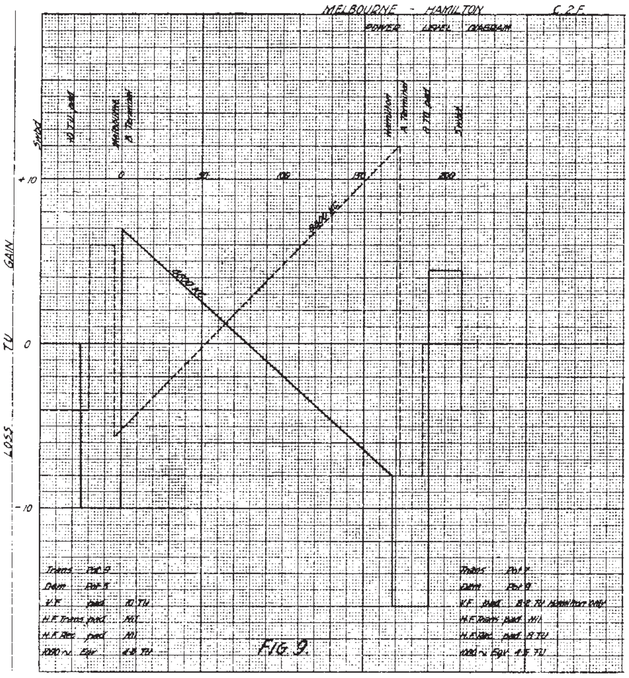


FIG. 9.

Power Level Diagram, Melbourne-Hamilton.

by the assignment of land to returned soldiers, and the town must progress by virtue of its position on the banks of the river Murray. This telephone traffic centre was connected to Melbourne by a 300 lb. copper non-repeatered aerial trunk line serving the intermediate stations St. Arnaud, Birchip, Woomelang and Ouyen. To relieve traffic congestion and to provide a high grade transmission circuit to Mildura and the outlying areas, a carrier system was superimposed on this circuit, the carrier current being by-passed at the intermediate offices by means of carrier transfer filter sets.

With the installation of the carrier channel the trunk line was permanently divided at Birchip and arranged so that Birchip and St. Arnaud were given direct access to Melbourne on one half of the physical circuit. The other half was used for local traffic between the intermediate stations and for conversations extending through Mildura to Melbourne. In effect, then, a Melbourne subscriber calling Birchip can be switched over one of two circuits,

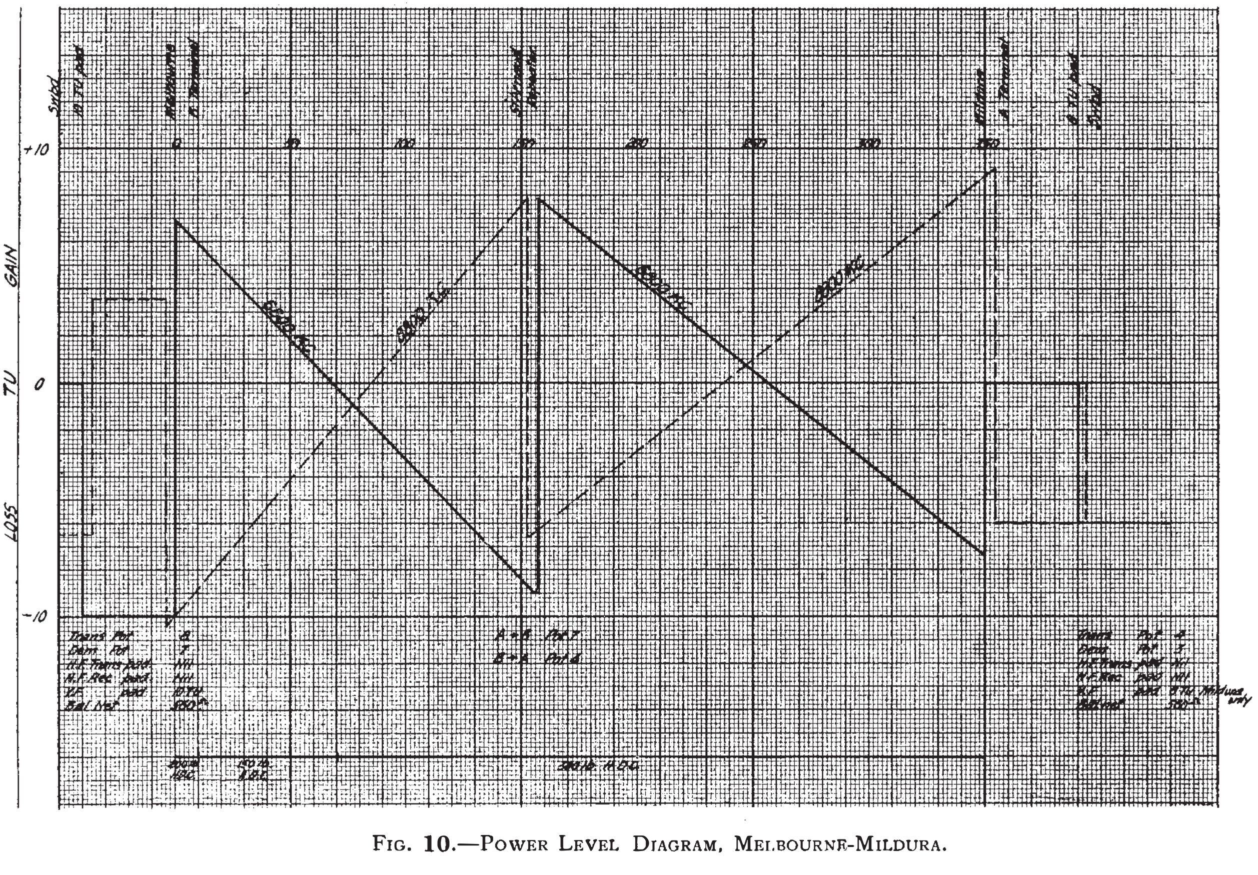


Fig. 10.—Power Level Diagram, Melbourne-Mildura.

the one by the physical trunk having 1000 cycle equivalent 12 TU and the other over carrier to Mildura and thence back *via* physical to Birchip, having an equivalent of approximately 7 TU. The transmission equivalent of the original circuit at 1000 cycles was 16 TU. This included the loss in the transfer filter sets.

To ensure that the line was free from irregularities other than the unavoidable lengths of trunk entrance cable, impedance and attenuation measurements were taken over the range 4000 to 30,000 cycles. The line was by no means free from irregularities and a study of the graph in Fig. 7 revealed the existence of unknown irregularities, the majority of which lay between St. Arnaud and Birchip. The special line party detailed to make a thorough examination of the trunk located all of these, and the satisfactory state of the line after the examination is revealed by the graph in Fig. 8. The 10% variation in the mean characteristic impedance was due entirely to the presence of a length of trunk entrance cable used to lead the trunks under the railway line and into the office.

This system can be used to give a 6 TU conversation when used for Mildura subscribers by the switching in of a 6 TU pad in the voice frequency circuit operated by a relay connected to the spring contacts of the local jack. The circuit will also give a 2 TU conversation when used for Ouyen subscribers, and as Ouyen is the switching centre for Euston in New South Wales and Pineroo in South Australia we are able to carry out a conversation with Melbourne over 500 route miles with an equivalent not greater than 9 TU. As in the case also of the Hamilton installation, we are able to extend this system to Sydney, Adelaide, and within a very short space of time to Brisbane. This last connection will be made possible by the completion of the multi-channel system between Sydney and Brisbane. Conversation from Pineroo to Brisbane will then be approximately 2,000 route miles, and the equivalent will not be greater than 15 TU.

THE USE OF A WENTE CONDENSER TRANSMITTER TO MEASURE SOUND PRESSURES IN ABSOLUTE TERMS.

A. J. Aldridge, A.C.G.I., A.M.I.E.E.

WENTE Condenser Transmitters have now been in use for some ten years or more, both as practically distortionless transmitters for speech and broadcasting and as a means of measuring sound pressures. It is probably not generally known that their use, without suitable corrections, may involve certain errors which it is proposed to indicate here. These errors have been referred to by Mr. E. J. Barnes in the discussion on Captain Cohen's I.E.E. paper (read 17.11.27).

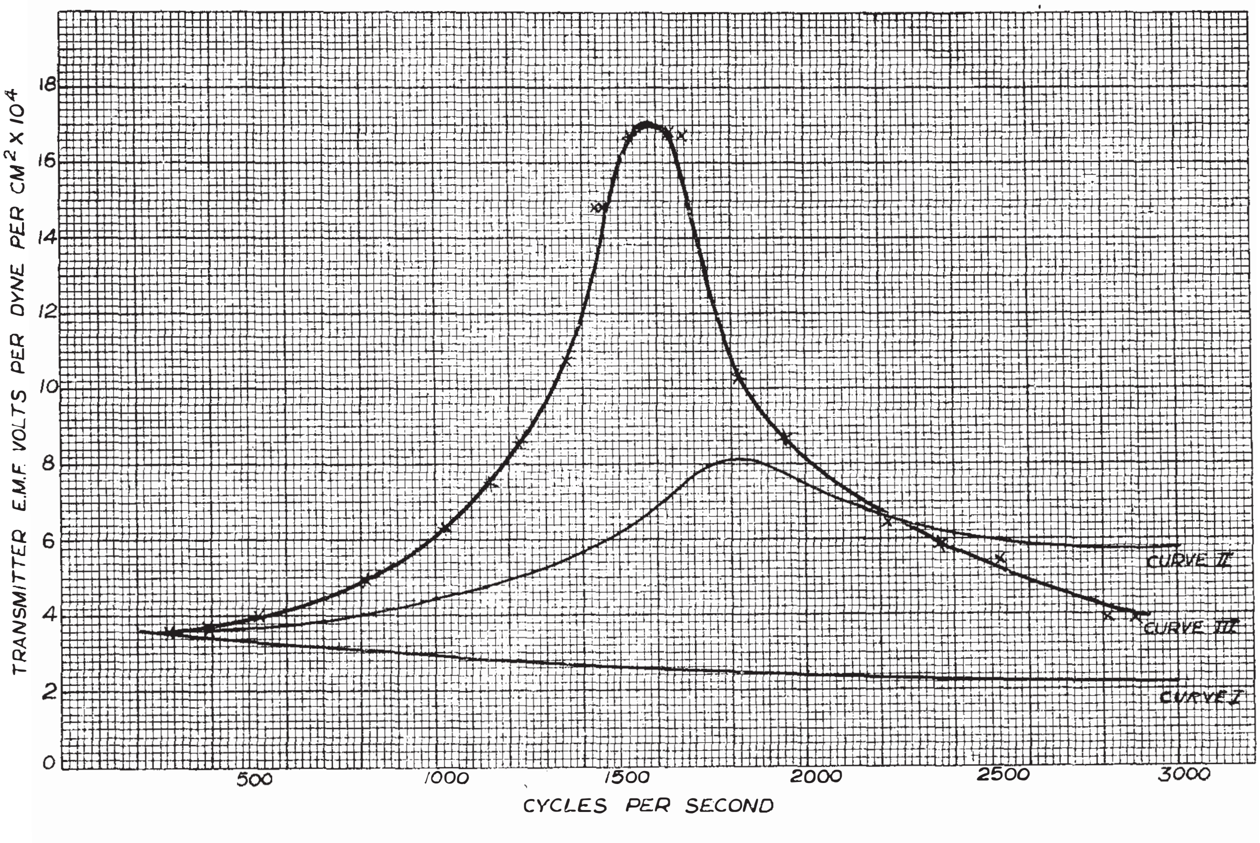
So far as is known, no calibration curves have been published other than those supplied by the makers. It is not suggested that these are inaccurate, but the calibrations are carried out in a certain manner and are not, in many cases, applicable to the conditions in which the instruments are used.

As is probably well known, the calibration is carried out by means of a thermophone. This consists of two slips of gold foil mounted upon a plate which is caused to fit airtight in the recess in front of the transmitter. A known direct current is passed through these strips and superimposed upon this current is a known alternating current of any desired frequency. The small space between the transmitter diaphragm and the thermophone mounting plate is kept filled with hydrogen gas under atmospheric pressure. Knowing the dimensions of the foils, and of the chamber in which they are, it is possible to calculate the alternating sound pressure developed by the passage of the alternating current through the foils. The calibration curve is the ratio of the E.M.F. developed by the transmitter to this sound pressure in dynes per square centimetre.

Assuming the various constants are accurately known, and the computation is accurate, this gives a perfectly definite calibration, but it is at once evident that the transmitter will seldom, if ever, be used in the condition in which it is calibrated, and unless corrections are applied errors will be introduced. The following appear to be the chief sources of possible error.

(1) The calibration is made in hydrogen.

(2) The front of the transmitter is sealed with a small hydrogen-filled cavity, whereas in use it will usually be open to the air.



Condenser Transmitter No. 111 Type 370W. Frequency Characteristics.

(3) The air pressures in terms of which the calibration is given are the actual sound pressures actuating the diaphragm. In use the transmitter by its mere presence in a sound field will distort this field and cause the pressure at the position of the diaphragm to be greater than it was before the insertion of the transmitter.

Considering these in turn :—

(1) The effect of the hydrogen is probably negligible. It will slightly alter the damping on the diaphragm, but as by far the greatest damping is produced by the very small enclosed space between the diaphragm and the back electrode the other may be neglected.

(2) The enclosure of the front of the transmitter has three effects. The restoring force in the diaphragm will be somewhat increased, tending to raise the natural frequency ; the additional load on the diaphragm due to the air which must be moved when the transmitter is is used in the open is absent, and this will also raise the natural frequency. Neither of these effects is likely to be serious except at resonance, and as this is usually outside the range of frequency over which the transmitter

is used, the effects may probably be neglected. The third effect is, however, important. The diaphragm is set in the case about 1.5 cm. below the front, and hence there is left, when the transmitter is used in the open, a shallow tubular resonator. The effect of this is shewn in the curves in the figure based on tests carried out in the P.O. Research Laboratory by Mr. West on a 370W type transmitter. Curve I gives the calibration in terms of the actual pressure on the diaphragm and corresponds to the calibration supplied by the makers. Curve II gives the calibration in terms of the pressure at the position of the diaphragm in the sound field, before the introduction of the transmitter. It will be seen there is a pronounced resonance present, masked, to some extent, by an effect referred to under (3). Curve III is taken under conditions similar to those for Curve II, except that the recess has been artificially doubled in depth without altering the diameter.

Considering the space as a tubular resonator, and allowing for the end correction, the calculated resonance frequencies for the two conditions are 2600∽ and 1800∽ which indicate that the effects obtained experimentally shew the right order of resonant frequency.

(3) A sound wave striking any obstacle in its path will be partially reflected. The greater the ratio of the diameter of the obstacle to the wave length the more complete will be the reflection, until at high frequencies complete reflection will occur. The reflected pressure adds to the incident pressure, with the result that the actual pressure on the diaphragm is greater than that of the original sound field at the position of the diaphragm. If the transmitter is being used to measure sound pressures using the published calibration the effects of (2) and (3) will be to indicate pressures considerably greater than they really are.

It will be seen that at 1800∽ the pressure indicated is 3.1 times the true pressure.

With an ordinary Wente transmitter the reflection effect referred to causes an increase of pressure of about 50% at 1500∽

The effects of an obstacle in a sound field are being more fully dealt with by Mr. W. West in an article which will shortly appear.

The preceding remarks are of importance in connection with the C.C.I. Master Reference System.

A Wente condenser transmitter, having a somewhat smaller recess in front, has now been installed as part of the Master Reference Telephone Standard at the C.C.I. Laboratory in Paris, with thermophones for calibration. As previously stated, this gives a perfectly definite calibration and can be used to ensure that no change has occurred in the efficiency of the system. It must be remembered, however, that the calibration will not give the efficiency in absolute terms for the conditions of actual use, and this may give rise to misconception if comparative tests are made using transmitters of different shapes and sizes, or calibrated or used in other ways.

ROTTERDAM MUNICIPAL TELEPHONE SERVICE.

WE have received the official report on the Rotterdam Municipal Telephone Service for the year 1927. It contains some interesting information as to the development of the Ericsson Automatic system in a large commercial centre on the continent where the Municipality is distinguished for its progressive and enterprising attitude.

During the year reviewed, the third of the three main exchanges which provide the Municipal Service was converted to automatic working. With the completion of this work at Botersloot, which involved the transfer of the semi-automatic equipment from the Vlaggemans Street Exchange, automatic working is now installed throughout the Municipal area. At the end of the year 1927, the total number of subscribers' circuits was 20,804 (as compared with 19,752 at the end of the year 1926) of which 12,509 were connected to the Botersloot Exchange, 4,691 to the Korenaar Street Exchange and 3,544 to the Vlaggemans Street Exchange. So far as the Korenaar Street Exchange is concerned, 3,770 circuits, out of the 4,691, are now being worked wholly automatic, and all of the 3,544 circuits conected to the Vlaggemans Street Exchange.

The automatic plant fulfils all expectations and, as in the past, no serious interference with working occurred.

The increase in local traffic, compared with 1926, amounted to 4.2 million calls (the increase in 1926 over 1925 was 6.5 millions). The figures for the international traffic are interesting. While the number of calls with England diminished from 57,544 in 1926 to 53,829 in 1927, the calls with Germany increased from 280,940 in 1926 to 345,941 in 1927—an increase of 23.6%. The calls with Belgium fell from 125,115 in 1926 to 115,710 in 1927. The calls to France increased from 3,963 to 10,002 in 1927. Calls to Denmark, Czecho Slovakia and Switzerland also increased very substantially—there were nearly seven times as many calls to Czecho Slovakia, for example, in 1927 as in 1926, and nearly five times as many calls to Switzerland. New circuits to Austria, Dantzic, Italy and Hungary resulted in considerable traffic with these countries. The trunk calls from and to Rotterdam during the year 1927, were 3,408,450, an increase of 204,298 or approximately 9.5% compared with the previous year.

Appreciable increases also took place in the time and fire alarm services, but a reduction occurred in the number of telegrams forwarded over telephone circuits, the number of telegrams falling from 446,983 in 1926 to 408,617 in 1927; on the other hand, the number of telegrams delivered to telephone subscribers over their telephone circuits rose from 94,687 in 1926 to 103,913 in 1927.

The daily total of faults fell from 123.1 to 118.1 in 1926.

The profit on the whole undertaking amounted to 989,141 Dutch florins in 1927, compared with 955,352 florins in 1926.

THE STANDARDISATION OF STATIONARY SECONDARY CELLS IN THE BRITISH POST OFFICE.

H. C. Jones, B.Sc., Eng. Hons.

TELEPHONE apparatus designed and installed during recent years has generally required considerably more power for its operation than had been the case previously, and it is not surprising, therefore, that the capacity of batteries in use in the British Post Office has increased enormously as a result. In 1919 the total capacity of batteries in use in the Post Office was 5,000 kilowatt hours. To-day it is approximately 30,000 kilowatt hours and by 1936 it is estimated it will have increased to 100,000 kilowatt hours. In one building alone there are now batteries working having 2,000 K.W. hours capacity, *i.e.*, 40% of the capacity of all the batteries in Post Office use in the country in 1919, whilst there are installations under consideration which may require batteries of double this size. The development is not confined, however, to large installations, for with the extended use of automatic apparatus and lamp signalling manual equipment, it is now necessary to work many small exchanges of 50 lines and less from secondary cells. During 1927, over 20,000 secondary cells of less than 300 Amp. hrs. capacity were installed by the Department's staff, making an estimated number 70,000 cells of these sizes in Post Office use at the present time.

It will be appreciated from the foregoing that the standardisation of all sizes of secondary cells has become an absolute necessity, as otherwise undue difficulties would be experienced when repairs are required. Non-standardisation would necessitate each repair being treated as a special job and would entail excessive time and labour. Detailed standardisation results in each plate renewal being a comparatively simple matter of routine.

Some four or five years ago the Department standardised in detail 11 sizes of stationary cells varying from 8 Amp. hrs. to 300 Amp. hrs. capacity, and consequently the installation of many small power plants that were required shortly afterwards was made a very simple matter. Probably about 95% of the small secondary cells in use at present are of these standard types. The stardardisation of large secondary cells up to the largest sizes was a matter which could not be dealt with rapidly, but it was appreciated that if the large new exchanges then under consideration were fitted with non-standard plates considerable difficulty would result in future when repairs were required. In 1925, therefore, five standard plates were agreed upon by the Department in conjunction with the Accumulator manufacturers, and it was arranged that all new batteries of above 300 Amp. hrs. capacity supplied to the Department should be fitted with plates of one of the agreed dimensions. This scheme standardised cells, as regards plate dimensions, from 8 Amp. hrs. to those of the largest sizes and ensured that future repairs on all batteries could be carried out economically.

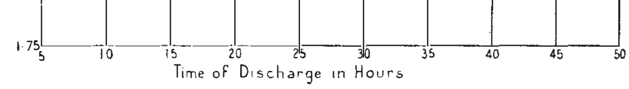


FIG. 1.—VOLTAGE OF CELL AT END OF DISCHARGE.

The scheme has now been completed in detail by the recent issue of "Specification for Cells, Secondary Stationary, Nos. 12/N to 16/N," in which every component required for the construction of any cells from 400 Amp. hrs. to 13,800 Amp. hrs. capacity has been definitely specified.

The following is a brief resumé of the chief points encountered in the work of standardisation. In the first place it was necessary to decide on a basis for the comparison of cells of various types and manufacture, and in order to do this the voltage at which a cell was to be considered discharged had to be decided. As a result of experiments, the curve shown in Fig. **1**, in which the voltage of a cell at the end of discharge is plotted against the rate of discharge, was produced and was agreed by the accumulator manufacturers. In passing, it will be noticed that it is from this curve, that the now familiar figure of 1.83 volts, which represents the P.D. of a cell at the end of a discharge at the 9 hour rate, is obtained.

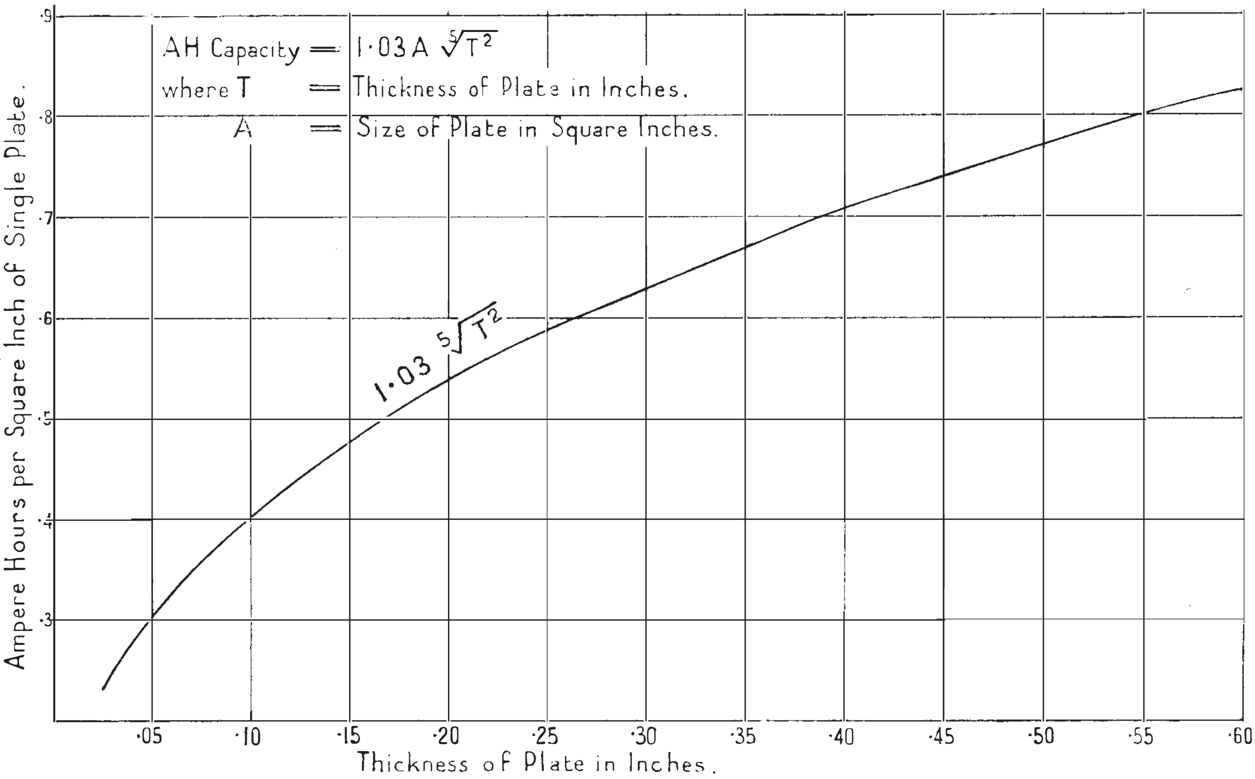


FIG. **2.**

A second problem was to define in what way the Amp. hour capacity of a cell was related to the dimensions of the plates. It was fairly obvious that the capacity was proportional to the superficial area, but it was not clear how it was affected by the thickness. As the result of tests on a large number and variety of cells, it was found that the capacity of plates, both positive and negative, as manufactured by the various reputable Accumulator firms, varied with the plate thickness as indicated by the curve shown in Fig. **2** and could be expressed by the formula : 1.03 area $\sqrt[5]{\text{thickness}^2}$ Amp. hours, the dimensions being in inches.

It should be noted that this formula does not hold good for all types of cells. Portable batteries, in which weight must be kept to a minimum, have a much higher capacity than is indicated by the above expression, but as a basis for comparing stationary cells, where weight and space are not vital considerations, but where long life is required, the formula has been found to be very accurate.

It was now possible to proceed with the actual design of the cells (we are considering for the moment those up to 300 Amp. hrs. capacity). At the outset three sizes of plates were decided upon as follows :—

Positive Plates.			Negative Plates.			Capacity of Positive Plates.
Width.	Height.	Thickness.	Width.	Height.	Thickness.	Amp. Hrs.
4″	4″	.2″	4″	4″	.15″	8
5″	6½″	12 mm.	5″	6½″	8 mm.	24
7″	9¾″	12 mm.	7″	9¾″	8 mm.	50

and it was arranged that these should be burnt up into sections containing 1 to 5 8-Amp. hour positive plates; 3, 4 or 5 24-Amp. hour positive plates, and 4, 5 or 6 50-Amp. hour positive plates. The negative sections contained one more plate than the corresponding positive sections.

Provision was made on each of the sections for bolted connections so that batteries could be erected by bolting together adjacent cells, no lead burning being, therefore, necessary. Eleven sizes of glass boxes suitable for containing the various sizes of sections and the other necessary components for building up batteries were also designed and standardised. By this means a comprehensive series of 11 sizes of secondary cells having capacities of 8, 16, 24, 32, 40, 72, 96, 120, 200, 250 and 300 Amp. hours was built up, the cells being styled "Cells, Secondary, Stationary Nos. 1-11." Arrangements were made for the Stores Department to hold stocks of these cells, both complete and in their separate components.

As no lead burning whatever is necessary, the erection and repair of batteries composed of these cells can be conveniently carried out by staff which is not specially experienced in battery work.

Now as regards the larger cells. The details of the five standard plates which have already been referred to are shown below:—

Nominal Capacity.	Positive Plates.			Negative Plates.		
Amps. Hrs.	Width.	Height.	Thickness.	Width.	Height.	Thickness.
100	10″	13″	12 mm.	10″	13½″	8 mm.
150	14″	14″	12 mm.	14″	14½″	8 mm.
200	14″	20″	10.4 mm.	14″	20½″	8 mm.
300	14″	30″	10.4 mm.	14″	30″	8 mm.
430	20⅝″	29″	10.4 mm.	20⅝″	29″	8 mm.

The standard plate pitch is 1¾″.

The standardisation of these plates was a big step forward. Hitherto each battery maker had supplied cells of his own special size and design, which frequently entailed difficulty as regards effective competition when plate renewals were required. Standardised plate dimensions obviated this feature. Previously the space allowed in the design of new buildings for battery equipment had to be on generous lines as, although the necessary Amp. hour capacity could be determined fairly accurately, the linear dimensions of the batteries were not definitely known. The standardisation of plate dimensions, however, permitted the necessary accommodation being accurately determined from a simple formula.

Following the agreement regarding plate dimensions the standardisation of the large batteries was proceeded with in detail. It was decided to adopt a somewhat unique scheme in which the plates were burnt together in convenient sections containing 2, 3 or 4 plates, arrangements for the inter-cell connections being made by bolting together adjacent positive and negative sections.

The positive plates were arranged to be made up into 2 or 3 plate sections and negative plates into 2, 3 or 4 plate sections. It is obvious that

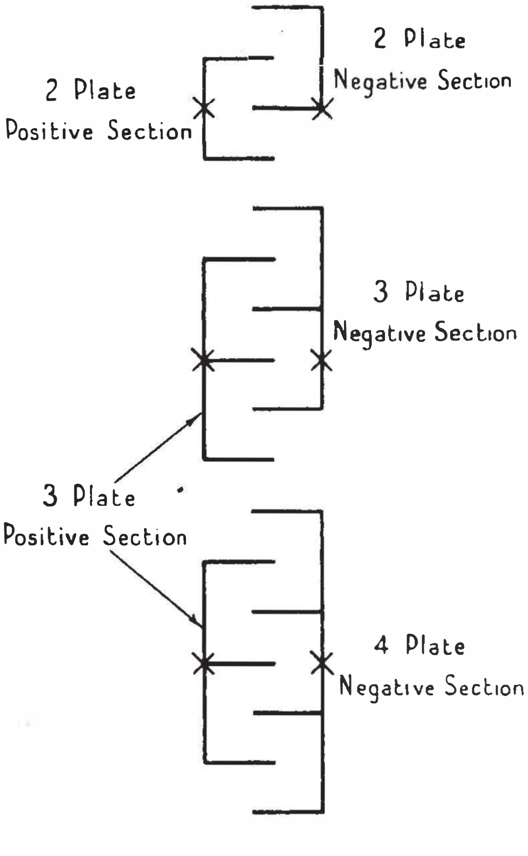


Fig. 3.

by a suitable arrangement of these sections a cell could be constructed containing any number of positive plates more than 2. The negative plate sections were arranged to be connected to positive sections containing the same number of plates, except at one end of the cell where the negative section contained one more plate than the corresponding positive section. This will be made clear from Fig. **3**, which shows diagrammatically the construction of a cell containing 8 positive plates. Fig. **4** shows clearly the construction of the plate sections and the method by which adjacent positive and negative sections are bolted together. This system of grouping plates in small sections of bolted connections obviates lead burning in exchanges and renders possible the ready removal of plates by the local staff for inspection, the straightening where necessary of buckled plates, the removal of short-circuits and enables replacements to be made with facility. It permits, where necessary, the use of deeper plates in existing boxes, seeing that by the removal of one or two sections a gap can be made for the removal of sediment. Moreover, any repairs or replacements may be carried out piecemeal whilst the battery is working. Additional

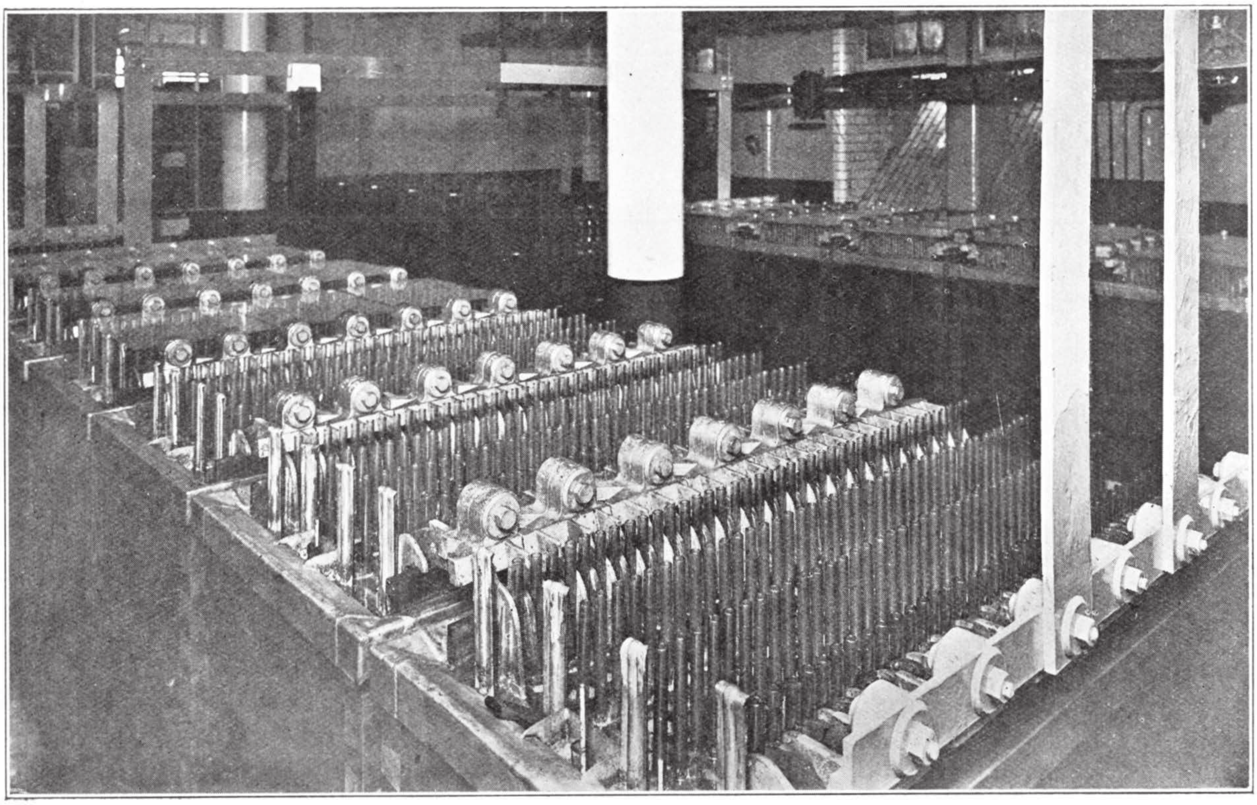


Fig. 4.—View of Cells showing Bolted Connections.

sections can easily be fitted to partially equipped batteries, either by adding previously charged sections to each cell if the existing plates are in good condition, or by re-distributing existing sections over fewer boxes and fitting the remaining boxes with new sections. The usefulness of the scheme will be appreciated from the following example. It was recently necessary to examine a battery where some slight buckling had occurred. A buckled plate having been located, the section concerned was removed from the cell, the plate straightened and the section replaced in the cell and bolted up again in five minutes.

In the new specification 113 sizes of cells have been specified in detail to cover a range of from 400 Amp. hours, using 100 Amp. hour plates to 13,800 Amp. hrs., in which cells 430 Amp. hr. plates are used. The following schedules give extracts from the tables in which the components required for the construction of these cells are specified in detail, and Fig. **5** shows in detail the construction of the cells and scheme of cell connections :—

PARTICULARS OF CELLS CONTAINING PLATES OF 299 AH. CAPACITY PER PLATE AT 9 HR. RATE.

	(b)	*(c)*					*(d)*								*(e)*			*(f)*	*(g)*	*(h)*	*(k)*	*(m)*		*(n)*	*(o)*
ll lary iary	Minimum Ah. Capacity at 9 hr. rate.	No. and Type of Sections.					Dimension of Box Wood No 15/n. (See Drawing 8795.)								Slabs, Glass, ⅜″ Thickness.			Separators Secondary Cell No. 7 $44\frac{1}{2} \times 12.55$ mm. 110 per cell.	Bolts Connection No. 6 per cell.	Insulators Battery No. 5 per cell.	Springs Secondary Cell No. 6 per cell	Spray Arrestors Width—16″.		Insulator Battery No. 6 No. per cell	Galls. of Acid Sulphuric No. 3 required per cell Sp.G. 1.215.
		Positive		Negative.																					
		15/2	15/3	15/2	15/3	15/4	A	B	C	D	E	F	G	H	Length	Depth	No. per cell.					Length	No. per cell.		
800	1790	—	2	—	1	1	13″	16$\frac{3}{8}$″	40$\frac{11}{16}$	$\frac{1}{2}$″	1$\frac{1}{2}$″	6″	1$\frac{3}{4}$″	21$\frac{1}{4}$″	12$\frac{1}{2}$″	41$\frac{15}{16}$	2	56	2	4	4	11$\frac{1}{4}$″	1	—	24.5
100	2090	2	1	1	2	—	14$\frac{3}{4}$″	16$\frac{3}{8}$″	40$\frac{11}{16}$	$\frac{1}{2}$″	1$\frac{1}{2}$″	6″	1$\frac{3}{4}$″	21$\frac{1}{4}$″	14$\frac{1}{4}$″	41$\frac{15}{16}$	2	64	3	4	4	13″	1	—	27.7
400	2390	1	2	1	1	1	16$\frac{1}{2}$″	16$\frac{3}{8}$″	40$\frac{11}{16}$	$\frac{1}{2}$″	1$\frac{1}{2}$″	6″	1$\frac{3}{4}$″	21$\frac{1}{4}$″	16″	41$\frac{15}{16}$	2	72	3	4	4	14$\frac{3}{4}$″	1	—	31.0
700	2690	—	3	—	2	1	18$\frac{1}{4}$″	16$\frac{3}{8}$″	40$\frac{11}{16}$	$\frac{1}{2}$″	1$\frac{1}{2}$″	6″	1$\frac{3}{4}$″	21$\frac{1}{4}$″	17$\frac{3}{4}$″	41$\frac{15}{16}$	2	80	3	4	4	9″	2	—	34.2
000	2960	2	2	2	1	1	20″	16$\frac{3}{8}$″	40$\frac{11}{16}$	$\frac{1}{2}$″	1$\frac{1}{2}$″	6″	1$\frac{3}{4}$″	21$\frac{1}{3}$″	19$\frac{1}{2}$″	41$\frac{15}{16}$	2	88	4	6	4	10″	2	—	37.4

Fig. **6** shows a general view of two 11 cell batteries of 5650 Amp. hr. capacity constructed of 300 Amp. hr. plates. It shows clearly the construction of the battery stands, the supporting insulators, the method of supporting end cells, the interconnecting of the plate sections at the positive and negative ends of the battery, all of which points are covered in the specification.

It will have been noticed from an examination of Figs. **4** and **6** that except at the positive and negative ends of the battery, individual cell positive or negative sections are not interconnected. Theoretically this particular disposition of plate sections results in a transfer of current on charge and discharge diagonally across the battery and consequent unequal working of the plates. This is confirmed to some extent in practice by slightly uneven voltage readings, certain sections showing a tendency to attain a high voltage on charge and a lower voltage on discharge than other sections. This has led to a certain amount of difficulty in making the acceptance tests, as it has not been possible to determine by voltage readings exactly when a cell was discharged. It has, therefore, been decided to fit connection bars in the form of

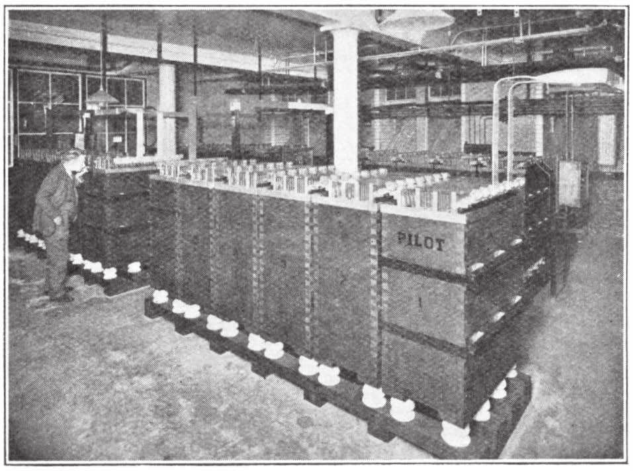
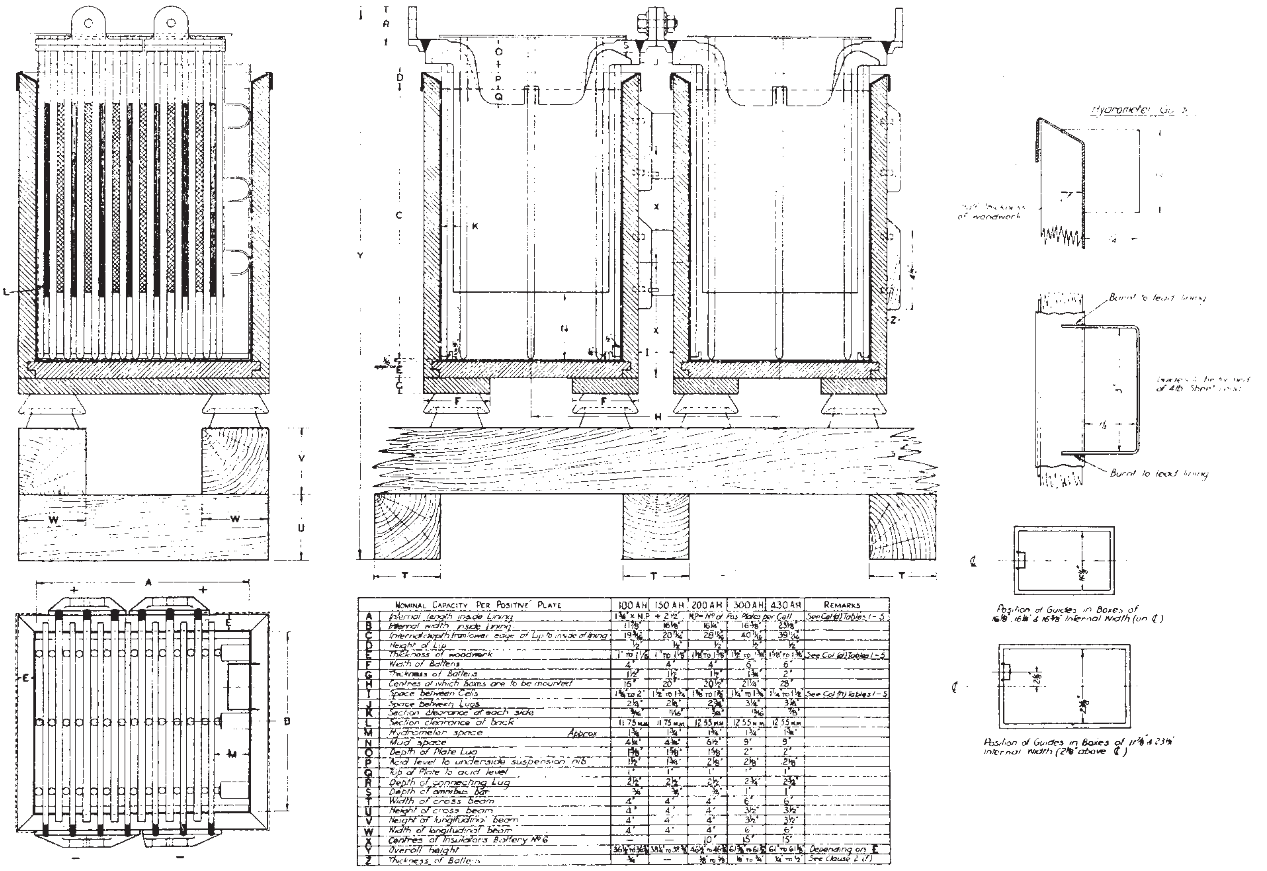


FIG. **6**.—STANDARD BATTERY OF 5650 AH. CAPACITY.

leadised copper strips so as to common the adjacent sections of individual cells. These will not interfere with the particular advantages of the bolted connection system previously enumerated, and will also nullify the possibility of any trouble which might have resulted from the unequal distribution of the current on charge and discharge.

There has been in the past a certain amount of controversy regarding the testing of secondary cells. All the relevant P.O. specifications, however, definitely stipulate what tests are to be applied and have clarified the position as far as the battery contractors and the Department are concerned. It is thought that particulars of the tests may prove of interest and the tests made in respect of the large cells are therefore given in some detail below.


A
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Q
R
S
X
Y
Z
Hydrometer Guide
Half thickness of woodwork
Burnt to lead lining
Guides to be made of 4lb Sheet Lead
Burnt to lead lining
Position of Guides in Boxes of 16⅛", 16¼" & 16⅜" Internal Width (on ℄)
Position of Guides in Boxes of 11⅞" & 23⅛" Internal Width (2⅛" above ℄)

	Nominal Capacity Per Positive Plate	100 AH	150 AH	200 AH	300 AH	430 AH	Remarks
A	Internal length inside Lining	1¾" × N.P + 2½" N.P = Nº of Pos Plates per Cell					See Col (d) Tables 1 – 5
B	Internal width inside Lining	11⅞"	16⅛"	16¼"	16⅜"	23⅛"	
C	Internal depth from lower edge of Lip to inside of lining	19 3/16"	20 7/16"	28 11/16"	40 11/16"	39 11/16"	
D	Height of Lip	½"	½"	½"	½"	½"	
E	Thickness of woodwork	1" to 1⅛"	1" to 1⅛"	1⅛" to 1⅜"	1½" to 1⅝"	1⅝" to 1⅞"	See Col (d) Tables 1 – 5
F	Width of Battens	4"	4"	4"	6"	6"	
G	Thickness of Battens	1½"	1½"	1½"	1¾"	2"	
H	Centres at which Boxes are to be mounted	16"	20"	20½"	21¼"	28"	
I	Space between Cells	1⅝" to 2"	1½" to 1¾"	1⅜" to 1⅝"	1¼" to 1⅜"	1¼" to 1½"	See Col (h) Tables 1 – 5
J	Space between Lugs	2¼"	2⅛"	2¾"	3¼"	3⅛"	
K	Section clearance at each side	3/16"	11/16"	⅝"	13/16"	⅞"	
L	Section clearance at back	11.75 mm	11.75 mm	12.55 mm	12.55 mm	12.55 mm	
M	Hydrometer space Approx	1⅜"	1¾"	1¾"	1¾"	1¾"	
N	Mud space	4¼"	4¾"	6½"	9"	9"	
O	Depth of Plate Lug	1⅝"	1⅝"	1⅝"	2"	2"	
P	Acid level to underside suspension nib	1½"	1⅜"	2⅛"	2⅛"	2⅛"	
Q	Top of Plate to acid level	1"	1"	1"	1"	1"	
R	Depth of connecting Lug	2½"	2½"	2½"	2¾"	2¾"	
S	Depth of omnibus bar	¾"	¾"	¾"	1"	1"	
T	Width of cross beam	4"	4"	4"	6"	6"	
U	Height of cross beam	4"	4"	4"	3½"	3½"	
V	Height of longitudinal beam	4"	4"	4"	3½"	3½"	
W	Width of longitudinal beam	4"	4"	4"	6"	6"	
X	Centres of Insulators Battery Nº 6	—	—	10"	15"	15"	
Y	Overall height	36½" to 36¾"	38¼" to 38¾"	46½" to 46¾"	61⅜" to 61⅝"	61" to 61¼"	Depending on E
Z	Thickness of Battens	¾"	—	⅜" to ⅝"	½" to ¾"	¼" to ½"	See Clause 2 (f)

FIG. 5.—STANDARD CELLS. DETAILS OF CONSTRUCTION.

In the first place, when tendering, the contractor is required to state the number of Amp. hours required for the initial charge of the batteries. The Department supplies this amount of power free of cost and also the power required for the test charge, provided this does not exceed 1/9th more than the guaranteed capacity of the batteries. Any excess power used is chargeable to the contractor at a rate of 3d. per B.O.T. unit.

The initial charge and preliminary or emptying discharge are given prior to the tests so as to get the cells into a cyclic condition. The preliminary discharge is continued for 9 hours at the 9 hour discharge rate, or alternatively at the 9 hour rate until the voltage of the battery falls to 1.83 × N, where N is the number of cells in the battery. The test charge is then immediately given at a rate which is determined by the contractor, but must not be less than the 8 hour discharge rate. The charge is continued at this rate until not less than 70% of the total charge has been given, when the current may be reduced to a rate not less than half of what it was previously and continued until the cells are charged to the contractor's satisfaction. After three hours, and before 12 hours have elapsed after the test charge, the test discharge from which the capacity of the battery is determined is commenced. The discharge is made at the 9 hour discharge rate and is continued until the voltage across the battery falls to 1.83 × N, N being the number of cells in the battery. The ampere-hour and watt-hour efficiencies are determined from the test charge and discharge. In the event of the guaranteed Amp. hour capacity being discharged before the battery voltage falls to the above limit, the amp.-hour and watt-hour efficiencies are determined from the readings taken down to the point at which the guaranteed Amp. hour capacity had been discharged.

During the tests, hourly readings are taken on each cell of specific gravity, the temperature of electrolyte and the voltage, but towards the end of the test discharge, $\frac{1}{4}$ hourly readings are required, not less than five $\frac{1}{4}$ hourly readings being necessary. All specific gravity readings are corrected for temperature to 60°F., by adding .001 to the hydrometer readings for each 3°F. by which the temperature exceeds 60°F., or by deducting .001 for each 3°F. by which the temperature is less than 60°F. The ampere-hour capacity obtained on the test discharge is also corrected for temperature, by deducting .5% of the ampere-hour output obtained on test for each degree Fahrenheit by which the temperature of the electrolyte exceeds 60°F., or by increasing the capacity by .5% for each degree Fahrenheit by which the temperature of the electrolyte is less than 60°F. The temperature on which this correction is based is the mean of the average temperature readings of the electrolyte of all the cells taken during the last 15 minutes of the test discharge.

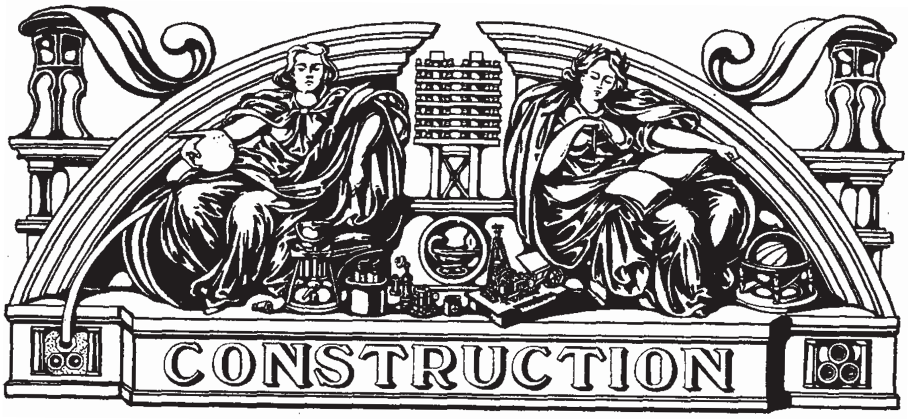
In addition to the cells themselves, instructions and apparatus for their maintenance have also been definitely standardised. The Secondary Cell Log Book, which was introduced in 1919, lays down the necessary regulations as regards day-to-day maintenance. As the maintenance is carried out on the specific gravity method, suitable hydrometers with specially long scales to facilitate accurate measurement have been designed and three types cover the whole range of cells. Hydrometers No. 9 are used with Cells, Secondary, Stationary, Nos. 1 to 8; Hydrometers No. 8 complete with a float, which enables the scale to be read about 1″ above the surface of the acid for Cells Secondary Nos. 9 to 11; and Hydrometers No. 12, which are to be used in the near future for all cells above 300 Amp. hrs. capacity.

Thermometer No. 1, a special floating type instrument, has been standardised for the determination of the temperature of the electrolyte.

A convenient instrument known as the Electrode Cadmium has been designed so as to enable Cadmium readings, which is a well-known method of isolating trouble in secondary cells, to be taken.

In conclusion, the anti-spray oil film which is used on all stationary cells in the British Post Office should be mentioned. The oil used is very pure petroleum and is standardised under the title of Oil, Insulating, No. 3. By its use, the spray of acid into the atmosphere has been prevented and the installation of batteries in the same room as the charging plant and exchange apparatus has been made possible. It has also resulted in a considerable diminution in the consumption of distilled water.

It is hoped that the foregoing, although not by any means a complete account of the standardisation of secondary cells, will serve in some small measure as an indication of the work which is being done in this growing branch of the Department's activities.



CONCRETE CONSTRUCTION.

By Lieut.-Colonel C. H. Fox, O.B.E., B.Sc. (Fellow).

[*Extracted from a Paper read before the Yorkshire Branch of The Surveyors' Institution at Leeds on the 24th March, 1927, and reprinted from the Journal of the Surveyors' Institution with the permission of the Council.*]

SUPERIORITY OVER OTHER MATERIALS.—No doubt the following are some of the reasons for the rapidly increasing adoption of this material in place of older established building materials. It is strong, impermeable to moisture, resists fire well, and does not harbour vermin. It does not deteriorate with age, but actually grows stronger as has been proved by tests over many years, and therefore costs very little in upkeep. It will thus be seen to have many advantages over other building materials. It has greater strength than stone, bricks, or timber, and these, together with steel, all deteriorate with age and require a varying amount expending on upkeep. Steel rusts and needs constant applications of paint or other preservative. Timber and steel do not resist fire, the former burns while the latter expands, twists and buckles. Stone also splinters and cracks under extreme heat.

Reinforced concrete is a scientifically designed material utilising the best properties of the component parts. Concrete is relatively cheap, strong in compression, resists absorption of water, and is one of the best preservatives of steel. Steel is relatively dear, needs protection from the atmosphere, but is very strong in tension; so in reinforced concrete just sufficient steel is provided to take up the tensile and shear stresses in the combined member, and this is placed in the correct position for this purpose. The concrete supplies the main bulk, protects the steel, and resists the compressive stresses. Stone and timber are both relatively wasteful as structural members, for they are both stronger in compression than tension, and so have to be used in larger sections on account of this tensile weakness than would be the case if they were used like concrete to resist the type of stress they are best fitted for.

Freedom in Design.—Stone, bricks and timber all cramp design as there is obviously a limit to the size in which these can be obtained, and to the parts they can play in a structure, although these limiting conditions have led in the past to great ingenuity in design. Concrete, however, has no such restrictions, and almost any kind or style of building can be designed.

Materials easily available.—Another consideration in favour of concrete is that the main bulk of the materials of which it is formed, namely, stone and sand, can be found in practically all parts of the country, and only the cement (and in the case of reinforced work the steel) needs transporting from a distance, thus heavy transport expense is avoided and materials on the spot can be utilised. The stone needed is of such a small size that quarry waste and material that could only otherwise be used for filling can be utilised. In many parts of the country great tips of stone for which no use could be found are now being broken and crushed and sold as aggregate for concrete. Stone for masonry needs skilled workmen both to get and work it, and to fix it in position, Concrete can be largely made with semi-skilled labour under the supervision of a few skilled men.

Plasticity.—Stone is very expensive if worked to any but the simplest shapes, and the labour has to be repeated on each piece however many there may be alike. Concrete can be moulded or cast to any shape, and once a mould is made it can be used several times, thus reducing the cost. In this way artificial stone (or concrete) competes very well with stone if there is any quantity of repetition work. This is the real test of economy in concrete.

Generally.—Concrete is composed of a mixture of certain substances such as broken stone or brick, sand, and cement. The broken stone is usually known as the aggregate, and this forms the bulk of the concrete, while the sand and cement fills the voids between the particles and set and bind the whole mass together.

Voids, &c.—To obtain a concrete strong and impermeable it is necessary that the proportions of the aggregate sand and cement should be so arranged that all the voids in the coarser material are completely filled by the finer stuff. An ideal aggregate is one which contains all sizes of particles from the largest to the lowest limits so that the particles may pack well together leaving the minimum amount of voids. The sand again should vary in size so that this may fill all the voids in the aggregate. The cement then has to fill any voids in the sand and coat over the whole mass. Economy in concrete construction is obtained by making the concrete as strong as possible at the least expense, which usually means using the minimum amount of cement to form a dense compact mass. When once all the voids are filled and the cement is adhering to all the sand and aggregate, the maximum strength is obtained for the materials used. The addition of more cement will increase the strength but also the cost.

In plain mass concrete in its simplest form the percentage costs are as follows for a good average mix:—

Aggregate	25 to 30 per cent
Sand	20 to 15 ,,
Cement	40 per cent.
Labour	15 ,,

It will be seen that the cement accounts for over one-third of the cost.

A correctly graded aggregate can effect a saving of 10 per cent. over the cost of a badly graded one, so this point is most important.

Cleanliness.—All the substances used in concrete, *i.e.*, aggregate sand and water, must be clean and free from impurities such as sulphur, loam, earthly and vegetable matter, and if not in that state the aggregate and sand must be washed before use. Salt is an impurity cement and causes efflorescence and permanent to be avoided, as it retards the setting of dampness in the finished concrete.

Aggregate.—The aggregate must consist of some clean, hard, sharp and preferably angular material such as coke breeze, shingle, broken stone or brick, or crushed granite, and as to which is selected depends on what the concrete is required for, and which aggregate is most easily available. In making this selection for any particular work, regard must be paid to the grading of the material in addition to its toughness, hardness, and cost.

(A) *Coke Breeze*.—The advantages of coke breeze are that it is cheap, and forms a concrete light in weight and fairly fire-resisting; but against these must be set the disadvantages that it is porous, and has very little strength in compression. It is therefore no use for reinforced concrete, as its porosity allows damp to penetrate to the steel reinforcement, and so sets up corrosion. Other similar but inferior substances are confused with coke breeze, such as pan breeze, ashes and clinker, and these must be avoided, as they usually contain dust, unburnt or partially burnt coal and coke, and dangerous elements such as sulphur, which set up expansion in the concrete during setting.

Coke breeze is mainly used for such purposes as partitions, or inside linings to hollow walls or blocks, or for filling between steel joists in floors, or any position where lightness is essential and the porosity is an advantage rather than a disadvantage. Nails can be easily driven into coke breeze concrete and obtain a firm grip.

(B) *Shingle.*—Shingle obtained from river beds or pits, or even the seashore if efflorescence is of no importance, form a concrete of great strength. River or sea shingles are usually free from loam or clay, whereas that from pits is usually coated with these. If loam or clay are present, the particles of these prevent the cement adhering to the aggregate, and so interfere with the binding together of the mass, and reduce the compressive strength. Thus pit sand must be well washed before use. An angular aggregate usually makes a stronger concrete than a smooth one, so crushed shingle is to be preferred to smooth water-worn stones. Similarly when used in fire-resisting construction shingle should be crushed so as not to exceed ¾ inch, as it is apt to splinter at a high temperature when exposed to fire unless broken to a small size.

(C) *Limestone and Sandstone.* — Broken stones, such as limestone, sandstones and various crystalline rocks that occur geologically between the former and the igneous rocks like granite, are used for aggregate. Hard limestones, such as Portland stone, form a very strong concrete, but are apt to be disintegrated when exposed to fire. Sandstones, such as our local stones, form a good aggregate for concrete, subject to the same limitations as limestones, but must be carefully graded and washed. Angular, sharp and roughly square pieces should be used in preference to long thin or flaky ones.

(D) *Granite.*—Granite forms a strong hard-wearing concrete, and is much used for floor finishes, but it does not behave too well when exposed to fire.

(E) *Broken Brick.*—Broken brick forms one of the best concretes where resistance to fire is required. As old bricks are usually used for this purpose, they must be well cleaned of all dust, mortar, paper, &c. Some bricks contain some sulphur and unslaked lime, which cause expansion and cracking of the concrete. Fletton bricks should be avoided, as these have been proved to be responsible for unsound concrete.

Sand.—The sand, like the aggregate, must also consist of some clean hard and sharp material well graded in size in order that it may completely fill all the voids between the aggregate. Sand is frequently obtained from the process of crushing the aggregate from large blocks of stone, and all the small stuff that will pass a 3/16 in. mesh is usually classed as sand. The bulk of the sand grains should be between 1/16 in. and ⅛ in. in size with a small proportion of larger and smaller stuff. Sand is also frequently found in natural deposits. The sand should always be graded and measured separately to the aggregate, as otherwise there is no guarantee that they are in the correct proportions, and probably different batches of concrete will vary considerably in composition. If sufficient sand be used to fill up the voids between the aggregate, and just enough cement added to fill up the interstices in the sand, a much smaller amount of cement is needed than if the sand be omitted, and a stronger and more impervious concrete is obtained. Old mortar reground should never be used as sand for concrete, as it may contain impurities and even a small amount of unslaked lime which will blow and cause expansion and cracking. Old bricks ground up for sand are similarly unreliable, due to the risk of having old mortar still adhering to them.

Portland Cement.—In the early part of the 19th century a great demand arose for a reliable hydraulic cement due to the amount of engineering work in hand then. Several people in this country experimented to make an artificial mixture of limestone and clay, and the person usually credited with the invention of Portland cement just over 100 years ago is Joseph Aspden of Leeds.

Chemical Composition. The chemical composition of Portland cement may vary between narrow limits due to the nature of the raw materials used, but the following ranges cover all cases: Lime, 60 to 67 per cent.; silica, 19 to 27 per cent.; alumina and ferricoxide, 7 to 14 per cent.; and average figures would be lime, 65 per cent.; silica, 21½ per cent.; alumina and ferricoxide, 9½ per cent.; water, impurities, insoluble matter, &c., 4 per cent.

The writer has said nothing about the manufacture of Portland cement, but wishes to emphasise that it is a very scientifically manufactured material, and nowadays is so carefully watched and frequently tested at all stages of its manufacture by highly skilled chemists that the resulting product is of the highest uniform quality. In the last few years other cements than Portland have been put on the market for special purposes, such as white cement, rapid-hardening Portland cement, and aluminous cements.

White Cement.—White cement differs from Portland cement mainly in the fact that the ferric-oxide has been removed, thus eliminating the characteristics grey colour of Portland cement. This, unfortunately, is an expensive process, and at present is not done in this country, so "white" cement has to be imported. This material is used for surface work, as in artificial stone, rough-cast, &c., as it enables any colour of finish to be obtained by the addition of appropriate colouring matter. Portland cement can be coloured, but the result is much deader than when " white " cement is used. With white cement any natural stone colour can be obtained.

Rapid-hardening Portland Cement.—Rapid-hardening Portland cement is a true Portland cement of practically the same analysis, but it is ground very much finer, and this process adds slightly to the cost, say about 15 per cent. The only difference in the chemical analysis is a slight decrease in the silica content and a corresponding increase in the alumina, and a typical analysis of a rapid-hardening Portland cement would be: Lime, 65 per cent.; silica, 20 per cent.; alumina and ferric-oxide, 11 per cent.; water impurities and insoluble matter, 4 per cent. In a Portland cement the aluminates of calcium (*i.e.,* alumina and lime compounds) produce the early hardening, while the silicates of calcium (*i.e.,* silica and lime compounds) produce the steadily increasing strength. It can thus be seen why rapid-hardening Portland cement, with its slightly greater alumina contents, hardens more rapidly.

Aluminous Cement.—Aluminous cement, as its name indicates, goes much further in making use of this property. It is not a Portland cement at all, but is made from limestone and bauxite, an aluminous mineral. The chemical proportions are altogether different to Portland cement. The lime is now about 39 per cent. instead of 65 per cent., silica 8 per cent. instead of 21½ per cent., alumina and ferric-oxide 51 per cent. instead of 9½ per cent., and remaining items 2 per cent. instead of 4 per cent. Aluminous cement, as may be expected from a consideration of its composition, hardens very rapidly, more so than rapid-hardening Portland cement, but does not increase in strength so quickly afterwards. Aluminous cement is relatively expensive, almost twice the cost of Portland cement, because very little bauxite is obtained in England, and this has to be imported, mainly from France. The name adopted almost universally in England for rapid-hardening Portland cement is " Ferrocrete," whilst the best known aluminous cement is " Ciment Fondu," the name given to it in France, whilst the best known English brand is " Lightning " brand.

Advantages of Rapid-hardening Cements.—These newer cements therefore overcome what has been one of the principal disadvantages of Portland cement concrete, namely, the long period of waiting for the concrete to set sufficiently hard, and the consequent tieing up of expensive formwork and scaffolding. These newer cements effect a considerable saving of time and money in freeing the formwork much more quickly, so that it can be taken down, re-erected and used again more frequently. Where Portland cement concrete takes 28 days to mature before full loads can be applied, Ferrocrete takes only three days and aluminous cement one day. In addition Ferrocrete or aluminous cements give a permanent strength at least 50 per cent. higher than Portland cement. It is possible, therefore, to use less of these cements to obtain an equal strength without losing any of the rapid-hardening properties. Without doubt Ferrocrete will displace Portland cement more and more for almost all work, but aluminous cement is hardly likely to be used except for special cases on account of the extra expense. There is one point against the latter cement, and that is that it must be kept entirely apart from Portland cement and never used along with it, as Portland cement dilutes the former and removes from it all its rapid-

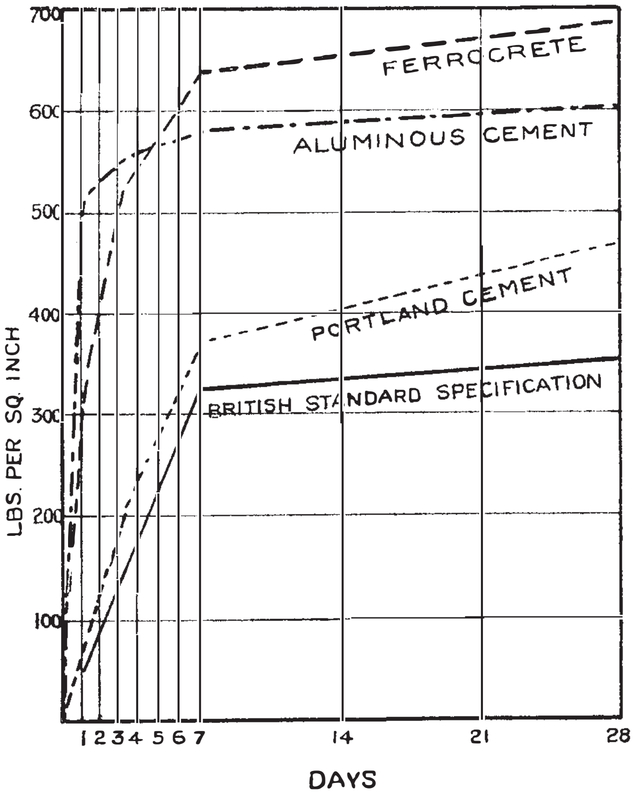


FIG. 1.—TENSILE TESTS. CEMENT AND SAND 1 TO 3.

hardening qualities. On the other hand, Ferrocrete is not affected by Portland cement, in fact, it is merely Portland cement of superior make. Aluminous cement is darker in colour and makes a darker concrete. Figs. **1** and **2** show the strength comparisons of the three cements with sand (tensile), and 1-2-4 concrete in comparison with Portland and Ferrocrete.

There is a further point in favour of both Ferrocrete and aluminous cements, and that is that concrete made of these is much less affected by frost: (1) The concrete hardens so quickly that frost cannot affect its initial set; (2) the setting of these cements is accompanied by a rise of temperature which resists the frost. These cements resist the action of sea-water and acids.

Size of Aggregate.—Having considered the types of aggregate sand and cement which, together with clean water, constitutes the components of concrete, the next thing to consider is the size of the aggregate and the relative proportions of the aggregate sand and cement for the concrete required. In ordinary mass concrete for foundations, stones up to 3 inches diameter can be used; but for walls, floors, columns and reinforced work generally, nothing exceeding $\frac{3}{4}$ inch should be used.

Proportions to eliminate Voids. — It is desirable to test the voids in the aggregate and sand it is decided to use before settling the relative proportions. A simple way of doing this is to take the watertight vessel of known capacity and fill it flush to the surface with the selected aggregate, and then fill up with water. The water added represents the volume of sand required to fill the voids in the aggregate. The sand can be tested in a similar way; but it should be noted that both the aggregate and sand should be well wetted before the test is made, or some of the water will be absorbed. In practice the average percentage of voids in the aggregate is found to be about 40 per cent., and about 10 per cent. excess sand is usually added, making 50 per cent. in all. Similary the voids in the sand are found to be 40 per cent. in average cases, and adding 10 per cent. excess cement we again get 50 per cent. Thus the well-known proportion of

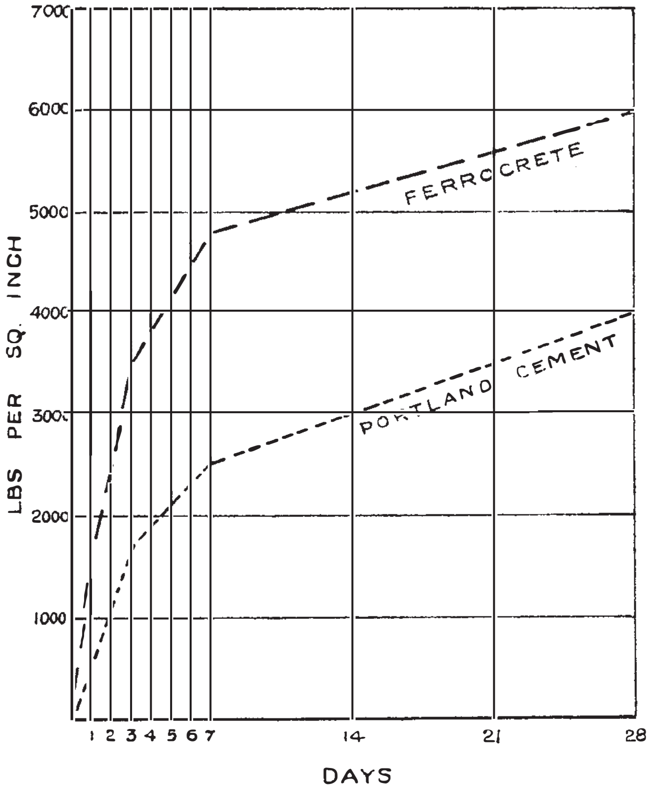


FIG. 2.—COMPRESSION TESTS. CONCRETE 1-2-4.

4-2-1 is arrived at, *i.e.*, 4 parts (by volume) aggregate and 2 parts sand to 1 part cement, and this in average cases gives a good compact concrete. However, if the aggregate contains a greater percentage of voids, it is necessary to add more sand and cement to obtain a compact concrete. A perfectly graded concrete may easily be stronger at 6-3-1 than a badly graded one made. 4-2-1. Thus it pays to test the voids. It should be pointed out that 4 parts of aggregate, 2 of sand and 1 of cement, do not give 7 parts of concrete, but only about 15 per cent. to 20 per cent. greater bulk than the aggregate alone, as the sand and cement are practically lost in filling voids.

Water.—One of the most important points affecting the final strength of the concrete is that of the correct amount of water used in the mix. The golden rule is to use as little water as possible consistent with providing sufficient to wet all the cement, and permit it to be thoroughly mixed with the other materials. The result of too much water is to slow the setting action and reduce the ultimate strength, besides giving rise to other troubles. The excess water ultimately evaporates and is replaced by air, thus forcing air voids. Too much water helps to cause contraction cracks. Sufficient water, however, must be provided to give perfect hydration of all the cement, and to permit the concrete to be placed into its position in the formwork. Thus the more elaborate the formwork and the more complicated the steel reinforcement the wetter must be the mix, and the wetter the mix the more rodding and tamping will the concrete require to consolidate it and force out all air bubbles, &c. Fig. **3** shows the loss of strength due to excess water.

Mixing. — Mixing, then, must be very thorough, and can be done either by machinery or by hand. If the former, a batch and not a continuous mixer should be used. The materials are measured by volume, placed in the mixer, which rotates, and the correct amount of water added. These machines give very uniform results, but the cost is justified only when there is a large amount of concreting to be done. The common method for small jobs is hand-mixing. In this the materials are measured on a mixing board or impervious surface, such as flags or concrete—never on the natural ground. The materials must be well mixed in a dry state by turning over the heap twice, then add water through a rose, and turn over the mass at least twice in a wet state until the concrete has assumed a uniform grey colour. The concrete should be mixed as close as possible to its final position and laid at once. It must be in position before any setting takes place, *i.e.*, within thirty minutes of the water being added.

Slump Test.—A modern and quite useful test for ensuring uniformity of mix is known as the slump test, and this is worth describing in detail, as this matter is much too important to be left to the personal whims of either the foreman or men mixing the concrete. When a person designs any building he assumes the materials will have a certain strength, and on that assumption provides a certain cross-section for each member. In the case of steel, timber, &c., he can rely more or less on certain strengths, but in the case of concrete he is at the mercy of those who make it on the job, and herein lies the chief difference between

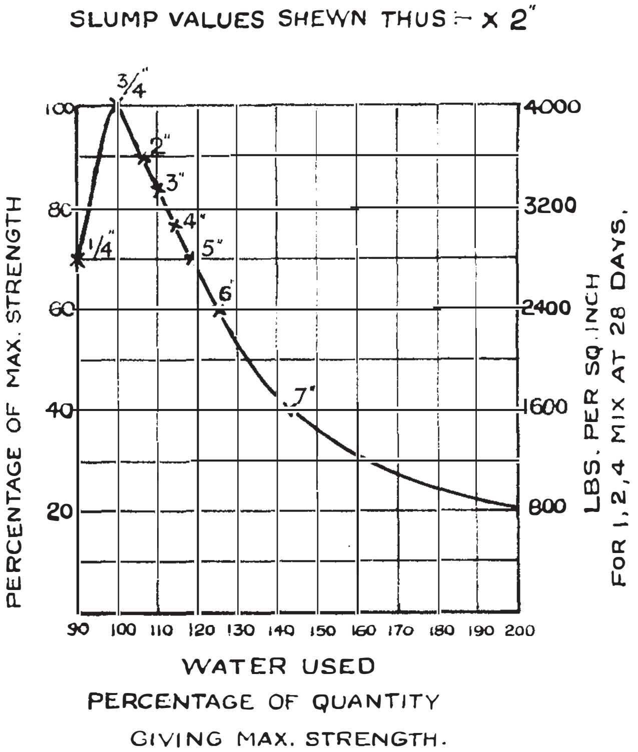


FIG. 3.—RELATION BETWEEN STRENGTH OF CONCRETE AND WATER CONTENT.

concrete and other materials. The apparatus required for the slump test is very simple, and consists of a sheet-metal truncated cone with open ends, 12 inches high, tapering from 8 inches diameter at the base to 4 inches diameter at the top, and fitted with two handles at the sides. To make the test, concrete is taken from any mix on the board and filled into the metal box 4 inches at a time, and rammed at each stage twenty-five times with a rod ¼ inch in diameter. After the box is filled the top surface is struck off level and the box lifted carefully away from the board. The concrete that was enclosed then settles down to an extent depending on its wetness. The wetter the mix the further it slumps (*i.e.,* settles down). The amount the concrete has settled is measured, and this is called the slump. A dry mix will only settle ½ inch to 1 inch, but a sloppy mix may settle as much as 10 inches. For mass concrete, or in sections easy to lay, a slump of 2 inches should be adopted. In more complicated work and thin vertical sections as great a slump as 6 inches may be required, but 3 inches or 4 inches is a good average. In any case the designer can settle what slump he intends to work to, and this test enables the workmen to check the mix at frequent intervals, preferably with each batch. If one batch is too wet the next can have less water, and so on.

Depositing in Position. — Concrete when mixed must be carefully placed in position, not tipped from a height, as this causes the cement and aggregate to become separated. It must be well tamped or rammed to consolidate it, and worked well into position and round any reinforcement.

Fire Resistance.—From the point of view of fire resistance concrete is an excellent material, provided a suitable aggregate is used and a sufficient thickness of cover provided to all embedded steel. Concrete of which the aggregate is coke breeze or broken brick resists fire best; limestone is not good, sandstone and gravel are a little better, but the gravel should be crushed; granite does not act well and is apt to splinter. A small aggregate is better than a large one for fire resistance..

Reinforcement. — The general principles of reinforced concrete, *i.e.,* the reason for embedding steel in concrete have been stated earlier. The principal material used for reinforcement is mild steel in plain round rods. This is steel with an ultimate strength of, say 28 to 32 tons per square inch. Other steels of higher tensile strengths such as medium carbon steel, cold twisted steel, and drawn steel wire, are also used, and are usually calcuated to resist stresses about 25 to 50 per cent. higher than mild steel. Drawn-steel wire is usually used in the form of a built-up fabric such as B.R.C., &c. Before it is used in concrete the metal must be clean and free from scale or loose rust, and must not be tarred, oiled, or painted, as oil or paint, &c., reduce the adhesion between steel and concrete.

The greatest care must be exercised to see that all reinforcement is placed exactly in the position indicated by the designer, and that it it not disturbed during concreting. If it is not in the form of built-up fabric it must all be tied together and carefully checked before concreting is commenced.

DESCRIPTION OF VARIOUS USES.

Some of the uses to which concrete is put will be briefly described with suggestions as to the best average proportions of the materials and the most suitable consistency under the slump test. Only average proportions are suggested as each aggregate should be tested to find the best grading, but for some uses a richer cement content is needed than for others. Similarly the values for slump are governed by the main rule that for strength the mix should be as dry as possible; but the rule has to be waived sufficiently to obtain a mix wet enough to flow into its position. Thus plain mass work can be very dry, but thin confined sections must be wettest.

In building work one of the first uses of concrete is in the construction of *foundations* and *walls.* Every wall should rest on a foundation of greater width than itself in order to spread the weight over as great an area as is required by the carrying power of the earth. The greater the weight the wider must be the foundations. In simple cases on good ground a plain mass foundation about 12 inches wider than the wall is sufficient, but if the ground is so weak as to need a much greater spread, the advantage of concrete is that the foundation can be increased and reinforced to stand the bending stress on the projections. In brickwork or masonry this would necessitate gradually spreading footings on top of the foundation. With a concrete foundation the wall can rest directly on it, thus economising in walling. If the ground is very weak, sometimes the best solution is to build the bottom floor as a *reinforced concrete raft,* so distributing the weight over the whole site. In other cases *piles* driven well into the ground can be used and the building erected on these. Slump for plain foundations, 2 inches; reinforced, 3 inches; proportions of aggregate sand and cement 6-3-1, or 8-4-1 if plain, but 4-2-1 if reinforced.

Walls.—Concrete walls can be used for buildings and for enclosing ground. Solid walls are usually adopted for boundary or retaining walls, dams, &c., whereas hollow walls are more usually adopted in buildings on account of the greater resistance of hollow walls to weather and temperature changes. Concrete walls are stronger than brick walls of the same thickness. Concrete walls can be built of pre-cast blocks walled like brickwork or be cast *in situ.* Much ingenuity—some of it wasted—has been devoted to the design of concrete blocks, especially in connection with housing, but the principal aims have been to provide a block with the following properties: (1) The block to be hollow with as large a cavity as possible, to save material and weight in handling; (2) the outer face to be impervious to the penetration of wet, and the inner face to be sufficiently porous to absorb condensation like plaster. Inner face often of coke breeze, into which nails can be driven; the outer face is often moulded to represent stone. There are numerous machines for block-making.

For *dam walls* concrete is almost invariably in mass form similar to masonry, though sometimes it is used as a core and faced with stone.

For walls to *retain earth,* however, it is more economical to use thin reinforced sections with a broad base or foundation projecting back under the earth. The earth resisting on this then helps to prevent the wall being pushed outwards and overturning. Counterforts at intervals connect the base to the front wall. This construction is only possible in concrete.

Slump for blocks, 1 inch to 2 inches; mass walls, 2 inches thin reinforced walls, 6 inches. Proportions, 6-3-1 for mass walls, 4-2-1 for reinforced work or blocks. Boundary walls can be left with surface rough to enable creepers, &c., to cling to them, and so improve the appearance. Corrugated iron as centering will give a flutted appearance to relieve the monotony of long unbroken surfaces.

Floors.—These can be laid either on the solid ground or suspended like wooden floors, and the suspended floors can be solid or hollow. In all suspended floors reinforcement must be used and so disposed as to take up the tenstile stresses. Roughly it may be stated that reinforcement must be placed at the bottom of all beams and slabs except over supports, where it must be on the top. In beams steel must be provided to resist shear stresses, but this is not necessary in slabs. Even floors on the solid are better reinforced, preferably with a light built-up fabric reinforcement, and this need not increase the cost. A 4-inch floor reinforced with a light fabric is as cheap as a 6-inch plain floor, and much less likely to crack.

Suspended floors in this country are usually of the beam and slab type, but in America the flat slab, or mushroom type, is more generally used. The reinforcement of this is much more complicated, but the resulting flat ceiling is of great benefit as regards lighting and resistance to fire. Hollow floors can be of many types, principally consisting of reinforced beams at close intervals, supporting hollow blocks of tile or concrete. Slump, 2 inches to 3 inches in slabs, 3 inches to 4 inches in beams. Proportions, 4-2-1 or 3-1½-1.

Flat Roofs.—Flat roofs formed similarly to floors, and usually water-proofed with rock asphalt or something similar. In factories the flat roof is sometimes used as a water tank.

Pitched Roofs.—The whole of the roof can be of concrete. Trusses, purlins, &c., can either be pre-cast and hoisted to position or cast *in situ.* The roof slabbing can be cast *in situ,* but pitches steeper than 25 degrees entail double shuttering, *i.e.*, top as well as bottom, to prevent the concrete slipping, and then cease to be economical. Roofing slabs or tiles, however, can be pre-cast at a very economical figure. Ceilings can be flat or curved. Slump for trusses, &c., 5 inches or 6 inches; slabs, 2 inches or 3 inches. Proportions, 4-2-1 or 3-1½-1. Tiles, &c., 3 sand to 1 cement.

Stairs.—Stairs can be made of concrete, either pre-cast or *in situ,* and reinforced. These are usually provided with non-slip treads. Slump, 3 inches. Proportions, 4-2-1.

Roads, Paths, and Pavings.—These can be constructed entirely of concrete. In the case of roads in towns concrete is frequently used for the foundation even where the actual surface is composed of other materials such as setts, asphalt, tarred macadam, wood blocks, &c., but there is no reason why the surface itself should not be of concrete. In America thousands of miles of concrete roads are in use. The following are the requirements of a good road: (1) It must be hard, firm and have a long life; (2) it must offer low resistance to wheel traffic; (3) it must be dustless and easy to clean; (4) the surface must be even but not slippery; (5) it must not be affected by climatic conditions; (6) the first cost must be reasonable and the maintenance low. Concrete most nearly satisfies these conditions. The usual construction is (1) a layer of balder or broken stone; (2) 8 inches to 12 inches of concrete plain or reinforced according to the nature of the ground. The road should be laid in short sections with elastic joints in order to avoid cracks that would occur if laid in long continuous lengths. 4-2-1 is a suitable proportion, and 2-inch slump is wet enough. Paths and pavings are built similarly, but with less depth of concrete, say 3 inches or 4 inches. A finishing coat of 1-3 Portland cement and sand, 1 inch thick laid on top before the first coat has set. This is important, as, if the foundation is allowed to set before the top coat is applied, there may be a poor bond between the two. When laid the surface must be protected from the sun or wind and left damp for some days to assist hardening. Very little camber is needed. Concrete curbs and channels can be used in substitution for stone on any kind of road.

Farm and Estate Work.—Farm and estate work offer and provide many opportunities for the use of concrete. Apart from the floors, walls, and roofs of buildings, and road, &c., already dealt with, concrete can be used with advantage for the following: Water tanks and cisterns, water troughs, feeding mangers, stall divisions, piggeries, fencing posts, and many other things. One reason for the wider adoption of the material is that much of it can be done without specially skilled labour; thus any surplus labour on the farm can be employed to make concrete blocks, fencing posts, &c.

Sewers, Water Mains, &c.—These can be made of concrete, and can either be laid *in situ* or pre-cast. Many firms specialise in making concrete pipes of all sizes, both round and egg-shaped. Up to 18 inches diameter, no doubt, concrete drains are more expensive than earthenware, but are stronger. They can be laid with unbroken joints inside. Mix needs to be fairly rich, and slump 6 inches or 7 inches.

Reservoirs, Water Tanks, &c.—Concrete is useful for the storage of water in reservoirs and swimming baths, and also in elevated tanks. Floors and walls can be quite thin, but need reinforcing. Fine materials, such as 1, 2 or 3 Portland cement and sand or fine gravel graded to form a dense concrete. Concrete can be made waterproof or lined with asphalt, &c.

Silos and Coal Bunkers. — Silos and coal bunkers, for storage of grain and coal, &c., are made of concrete. Same rules as for elevated water tanks.

Chimneys.—Same rules as for elevated water tanks.

Bridges.—Arched, solid, or latticed girder have been made up to 300 feet or 400-feet spans, although the latter are somewhat rare. The upkeep expense is practically nil.

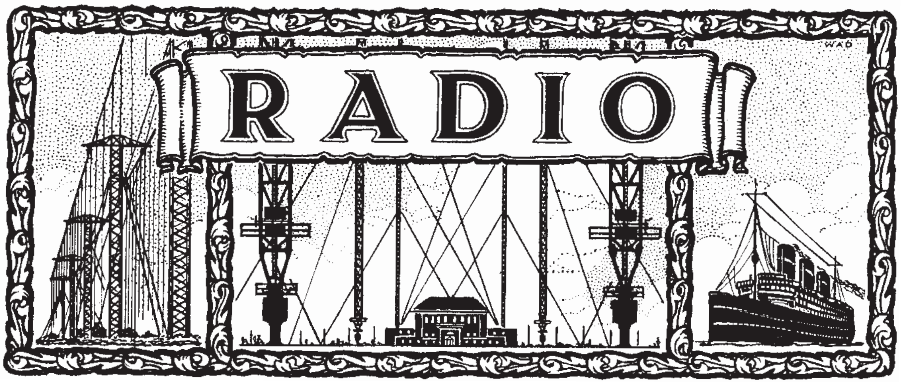
Harbour Work.—Wharves, piers, breakwaters, sea walls, floating docks, ships, &c. (latter up to 7,000 or 8,000 tons).

Railways.—For fencing posts, telegraph and signal posts sleepers, and even for bodies of trucks abroad.

Mines.—Used for sealing shafts, &c., and other uses.

CONCLUSION.

In conclusion, it is hoped the Paper may have proved of some interest by indicating the value of concrete as a building material for surveyors, as well as architects and engineers. It is equally suitable for use in small jobs as in large engineering works, and its possibilities have not yet been fully explored.



PORTISHEAD RADIO STATION.

THE completion of the new Portishead Radio Station in February, 1928, marked the passing of the first Post Office Radio Station equipped with a continuous wave transmitter, namely, at Devizes.

The Devizes Radio Station, which was originally intended as a receiving station in the England-Egypt link of the Imperial Chain (the masts only had been erected when the scheme was dropped) was equipped in 1919 with a Marconi 6 K.W. continuous wave valve transmitter for long distance ship and shore traffic mainly in the Atlantic. The plant comprising engines, batteries, transmitter and receiver were housed in existing Army huts.

In 1924 the Burnham Receiving Station was completed and in 1925 a second transmitter was installed at Devizes. Burnham then became the

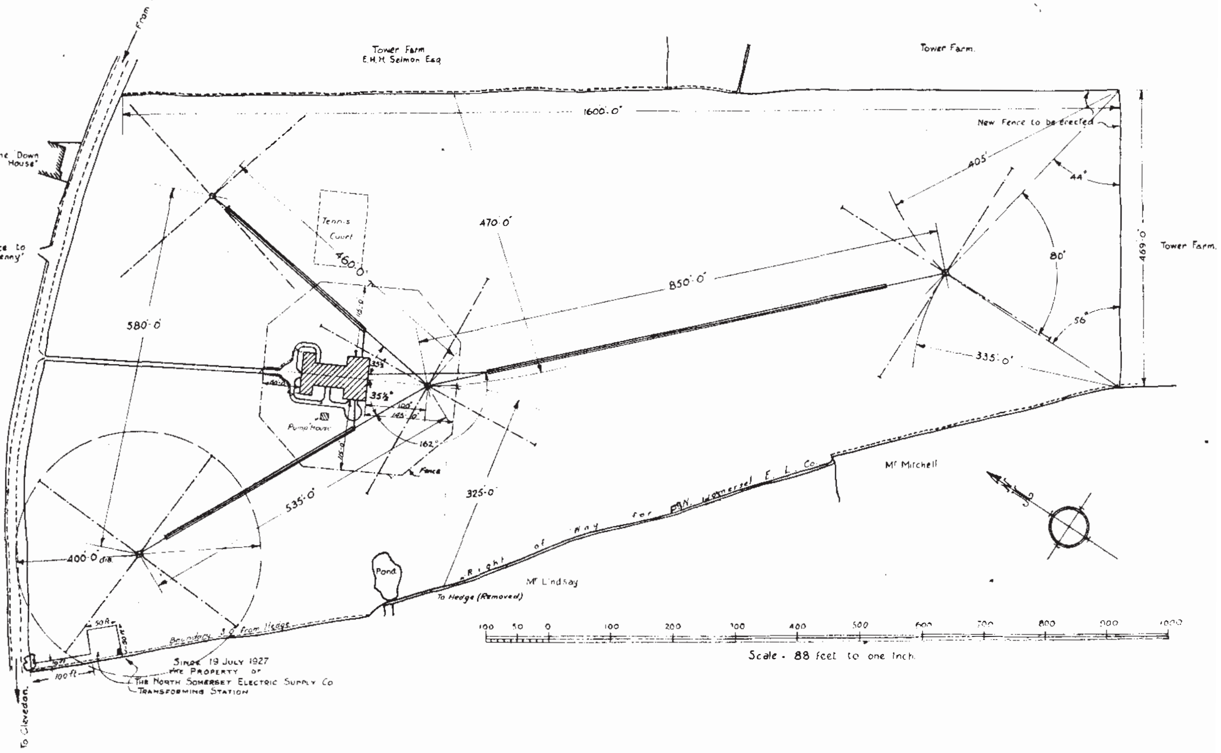


FIG. 1.—PORTISHEAD RADIO STATION. SITE PLAN.

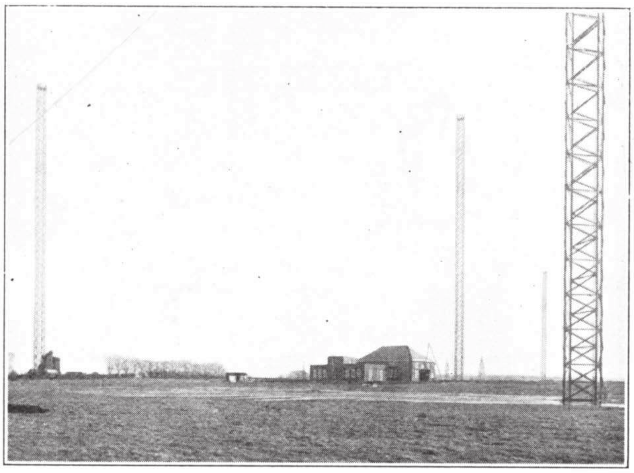


FIG. 2.—AERIAL SYSTEM.

receiving station and Devizes the transmitting station, control of the latter being carried out from Burnham. In 1926 the erection of a new transmitting station at Portishead near Bristol was authorised. As far as possible the design and installation of the plant was carried out by Post Office Engineers. The masts, power plant and transmitting plant were supplied by various contractors to P.O. design or specification, whilst the aerial and earth systems and all internal wireless plant were designed and installed by P.O. staff.

The plant at the new station consists of three tuning fork controlled transmitters fitted with coupled circuits, one taking 25 K.W. input (to the main transformer) and the other two, 6 K.W. input as compared with two 6 K.W. sets at Devizes. The sets were designed to give daylight ranges over sea of 1500-2000 miles, with increased ranges at night, but in practice these ranges are frequently exceeded and a regular schedule of working is maintained at night with ships just leaving New York harbour.

Site.—Burnham Radio Station, the receiving station for C.W. ship and shore traffic, is situated twenty-five miles south west of Bristol and it was desirable therefore that the transmitting station replacing Devizes should be located near Bristol, but not less than 20 miles from Burnham. Portishead fulfils these conditions and since it overlooks the Bristol Channel it is ideally situated for its purpose.

The station which is located one mile from Portishead and about nine miles from Bristol on a main road and telegraph route from Portishead to Clevedon, Weston-super-Mare and Burnham, stands on a stretch of down land 360 feet above sea level.

Masts, Aerials, etc.—A site plan is shown in Fig. 1 indicating the lay-out of the masts, buildings, etc. The design of three aerial systems in close proximity and excited on frequencies only a few kilocycles removed from each other necessitated a careful lay-out of masts and aerial systems in order to avoid interference and a reduction in efficiency. This has been done by, firstly, removing the 25 K.W. aerial as far as possible from the two 6 K.W. aerials and by disposing the last two approximately at right angles, and, secondly, by keeping each lead down as far apart as possible, the connections from the lead down to the building being disposed so as to reduce the coupling between them as far as possible.

The three aerial systems are supported from four 300′ masts of semi self-supporting type equipped with only one set of stays. They are of lattice steel construction, the cross section

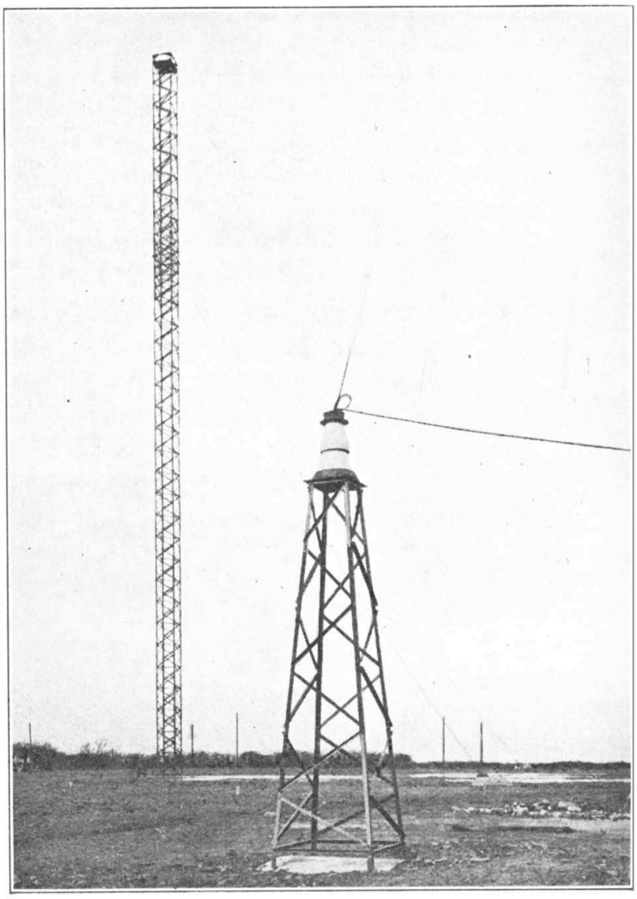


FIG. 3.—AERIAL SYSTEM.

being eight feet square, and are designed for a horizontal pull of four tons. They were manufactured by the Horsley Bridge Engineering Co., Ltd., and were erected on site by Messrs. C. F. Elwell. A good idea of the lay-out and construction is given in Figs. **2** and **3**.

Each aerial system is of sausage type and consists of six 7/14 silicon bronze wires on 6 ft. hexagonal spreaders. The spreaders are carried on a steel cable which takes the main strain on the aerial. The wires are bunched round 4″ diam. rings for the lead down, in order to reduce inductance variations and to reduce coupling between the three systems. The lead downs are anchored to short lead in towers and from these towers they are led into the transmitting building.

The earth system is common to all three transmitters and consists of wires buried over practically the full area of the site.

Power Supply.—Power supply is obtained from the North Somerset Power Supply Company at 400 volts 3 phase 50 cycles per second and is brought on to the main switchboard (installed by Messrs. Drake and Gorham Limited) shown in Fig. **4**, from which it is distributed to the transmitters and auxiliary machines. The main and filament transformers of each transmitter are fed direct from this supply and thus rotating machines are needed for auxiliary supplies only. To eliminate delays in starting and stopping the transmitters these auxiliaries are kept running continuously, and in order to maintain continuity of supply they are supplied in duplicate.

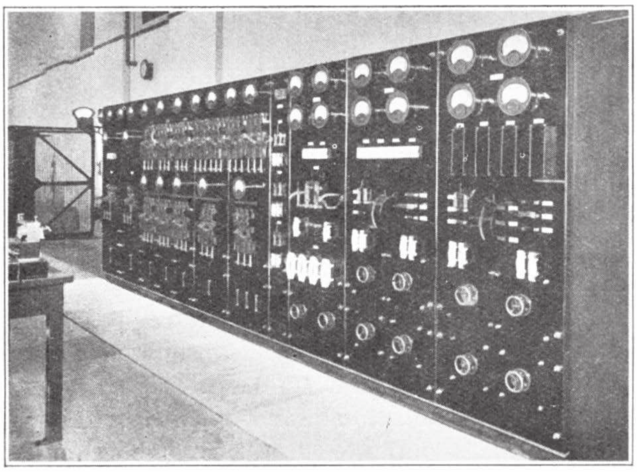


Fig. **4**.—Power Switchboard.

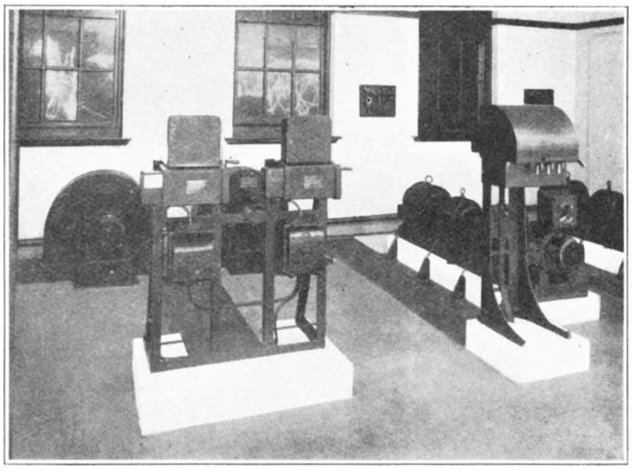


Fig. **5**.—Auxiliary Machines.

These auxiliaries consist of:—

(1) Motor-generator sets for the supplies to the Tuning-Fork Control Units, all four units being fed from one set. Each set consists of an induction motor and three D.C. generators, giving 6-10 volts for filament supply, 1200 volts for anode supply and 400 volts for grid bias on the main stages.

(2) A 3 H.P. Blower provides air blast for the silica valves of all three transmitters.

The small amount of running machinery is clearly brought out in Fig. **5**, which shows the auxiliary machine room.

Transmitting Plant.—The transmitting plant consists of three tuning-fork controlled transmitters, fitted with coupled circuits and capable of being adjusted to operate on frequencies between 100 and 150 kilocycles. The working frequencies are actually 121, 143 and 149 k.c. for the 25 K.W. and 6 K.W. sets respectively. Thus it will be seen that the frequency difference between the 6 K.W. sets is only 6 kilocycles or 4% of the actual frequency. Such a small difference in frequency necessitates a very careful design both of the transmitting plant and aerial systems, in order to avoid interference between the transmitters by either forced excitation or shock excitation due to keying. The experience gained on multiple station working at Northolt and Devizes enabled this to be accomplished satisfactorily with very little reduction in efficiency.

The general lay-out of the transmitting room

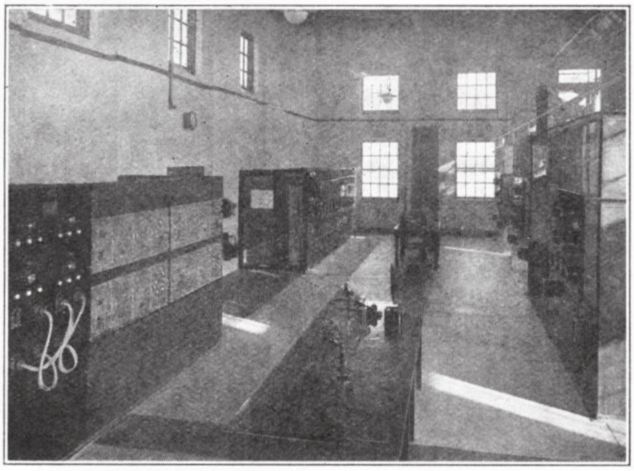


Fig. 6.—General Lay-out of Transmitter Room.

is illustrated in Fig. **6**, which shows the Tuning-Fork Units on the left front, the Power Switchboard beyond, the three transmitters on the right and the landline and control apparatus in the centre. The staff needed to handle such plant is small; each shift consists of two men, one at each table, and these men can easily handle the whole of the apparatus.

Tuning Fork Control Units.—The design of three transmitters working on frequencies very close together naturally made the interchangeability of portions of the high frequency plant a feasible proposition. It was decided therefore to separate the Tuning-Fork Control Units from the remainder of the transmitter and to mount them on a separate frame. The complete frame and distribution panel, Fig. **7**, are mounted at one end of the transmitting room and the output of these units, which provides the excitation to the power amplifiers, is distributed from a panel in the centre. Four T.F. Units are provided, one spare, and are so arranged that any one unit and its controls can be associated with any one transmitter. A description of the tuning-fork unit is contained in an article by Lt.-Col. A. G. Lee, O.B.E., M.C., in the *Electrician* for 1st May, 1925. The present units shown in Figs. **7** and **8** were designed and manufactured in the workshops of the Radio Section at Dollis Hill and represent a very considerable advance on the early models. Each unit consists of two copper screening boxes mounted one above the other, each box having four compartments which are completely screened from one another. The apparatus is mounted on the front panels, the connections between the stages in the various compartments being made by means of knife switch contacts mounted on the panels and boxes. Thus each stage can be easily removed

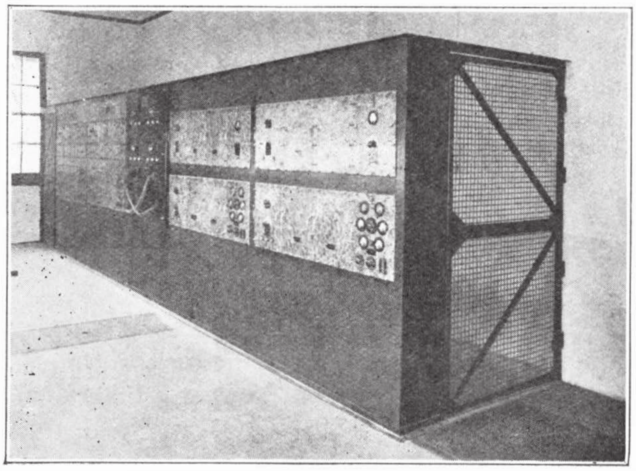


Fig. 7.—T.F. Enclosure.

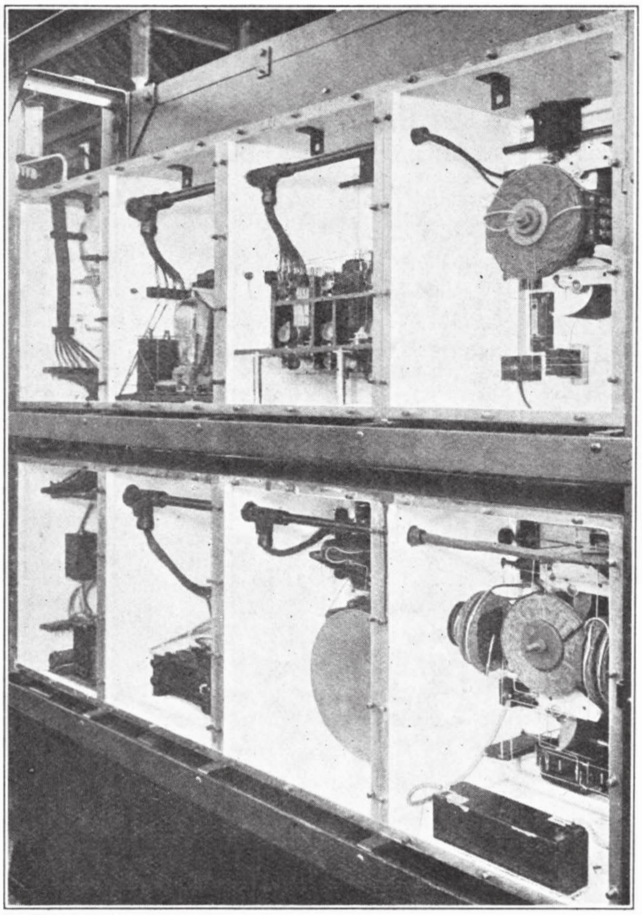


Fig. 8.—T.F. Unit. Rear View with Covers removed.

for examination, testing and repair if necessary.

Mechanical interlocking arrangements are fitted so that (1) no panel can be removed unless the 1200 volt supply has been switched off, and (2) this supply cannot be switched on unless all panels are in place. The bottom right hand panel is an instrument panel for the reading of filament voltages and of the valves in the various stages, anode voltages and currents. The output circuit is fitted on the right hand top panel.

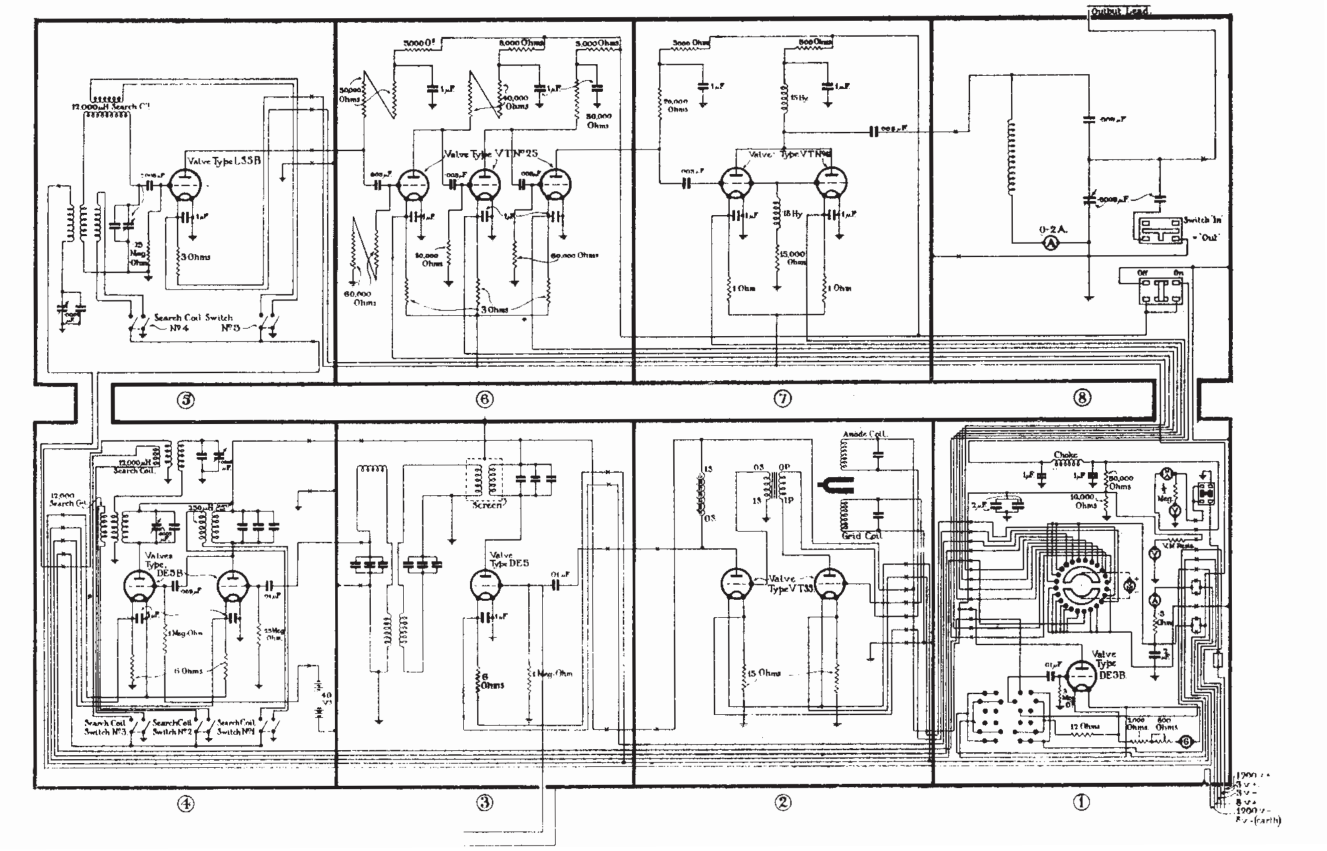


FIG. 9.—WIRING OF T.F. UNIT.

The wiring of a tuning fork unit is shown in Fig. **9**. There is a double multiplication of frequency in each set; for example, one tuning-fork controlled oscillator operates on 1833 cycles and after the wave form of this oscillation has been distorted by rectification, the 6th harmonic (11,000 cycles) is selected and amplified. This oscillation is then distorted and the 11th or 13th harmonic (121 or 143 kilocycles) selected and amplified. This amplified oscillation becomes the output of the tuning-fork unit and is then applied to the grid of the 1st power amplifier. Changes in frequency can be secured (*a*) by varying the frequency of the tuning fork itself by means of screws inserted in the prongs or (*b*) by selecting a different harmonic on either the 1st or 2nd multiplication. Except for one or two particular frequency changes, the frequency of a T.F. Control Unit is not varied in practice.

Power Amplifiers.—The arrangement of the power amplifiers is shown in Figs. **6** and **10**. The main transformer, rectifying valves and smoothing circuits are mounted at the back, the main amplifying valves on the left hand side and the 1st power amplifying valve on the right. An instrument panel fitted in the front centre gives readings of the currents, etc., in the various circuits. The tuned circuit of the 1st power amplifier is fitted behind this panel and the control handle for tuning this circuit is brought on to the instrument panel, as is also that of the aerial circuit variometer. Overload relays, in-

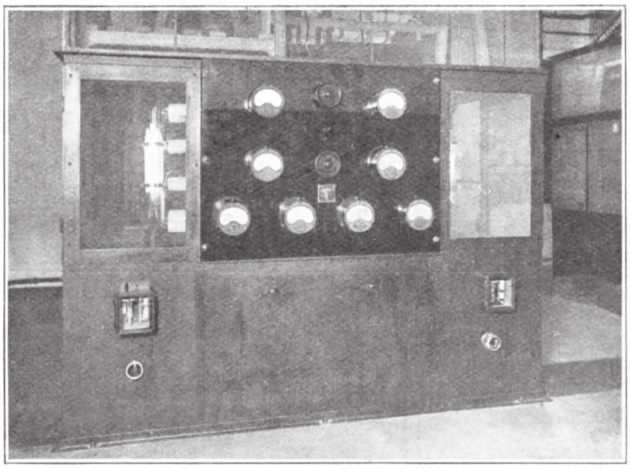


FIG. 10.—TRANSMITTER ENCLOSURE.

serted in the anode supplies to the power stages and arranged to cut off the supply in the event of sudden overloads, can be seen in Fig. **10** at the bottom corners of the enclosure.

The main tuned circuits are mounted over the amplifier enclosures in order to save floor space and to improve the lay-out. The primary and aerial coils of each transmitter are disposed at right angles, but the primary and aerial coils of all three sets are necessarily parallel to each other. The design of coil used by the Department is of pancake construction, and in consequence the magnetic field is not extensive along the axis of the coil but some distance removed from it, as would be the case if a long solenoid were used. In consequence the coupling between the coils of the various transmitters is negligible.

The wiring diagram of one transmitter is shown in Fig. **11**. The circuit employed has no special features, in fact, one might say that the main developments lie in the design of instruments, apparatus and lay-out rather than in the circuits.

The transmitters are equipped with glass and silica valves and give outputs as under :—

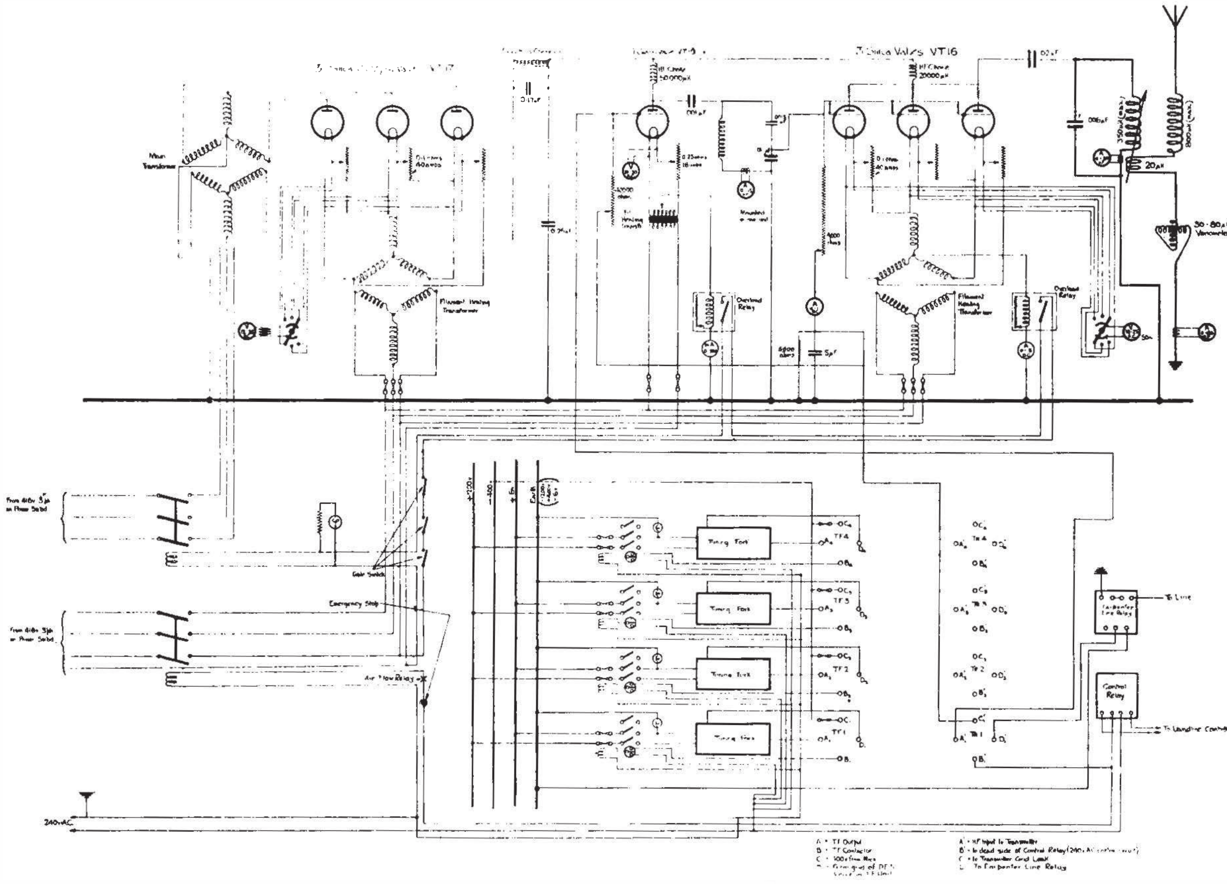


FIG. 11.—WIRING DIAGRAM OF ONE TRANSMITTER.

TRANSMITTER.	No. 1.	No. 2.	No. 3.
Power imput	25 K.W.	6 K.W.	6 K.W.
Wave length	2479 metres	2013 metres	2100 metres
Rectifying Valves	3-2.5 K.W. silica Type V.T. 17	3-1.0 K.W. glass V.T. 21	3-1.0 K.W. glass V.T. 21
Main Amplifying Valves	3-2.5 K.W. silica Type V.T. 16	1-2.5 K.W. silica V.T. 16	1-2.5 K.W. silica V.T. 16
Aeriel Current	55-60 amps.	28-30 amps.	28-30 amps.

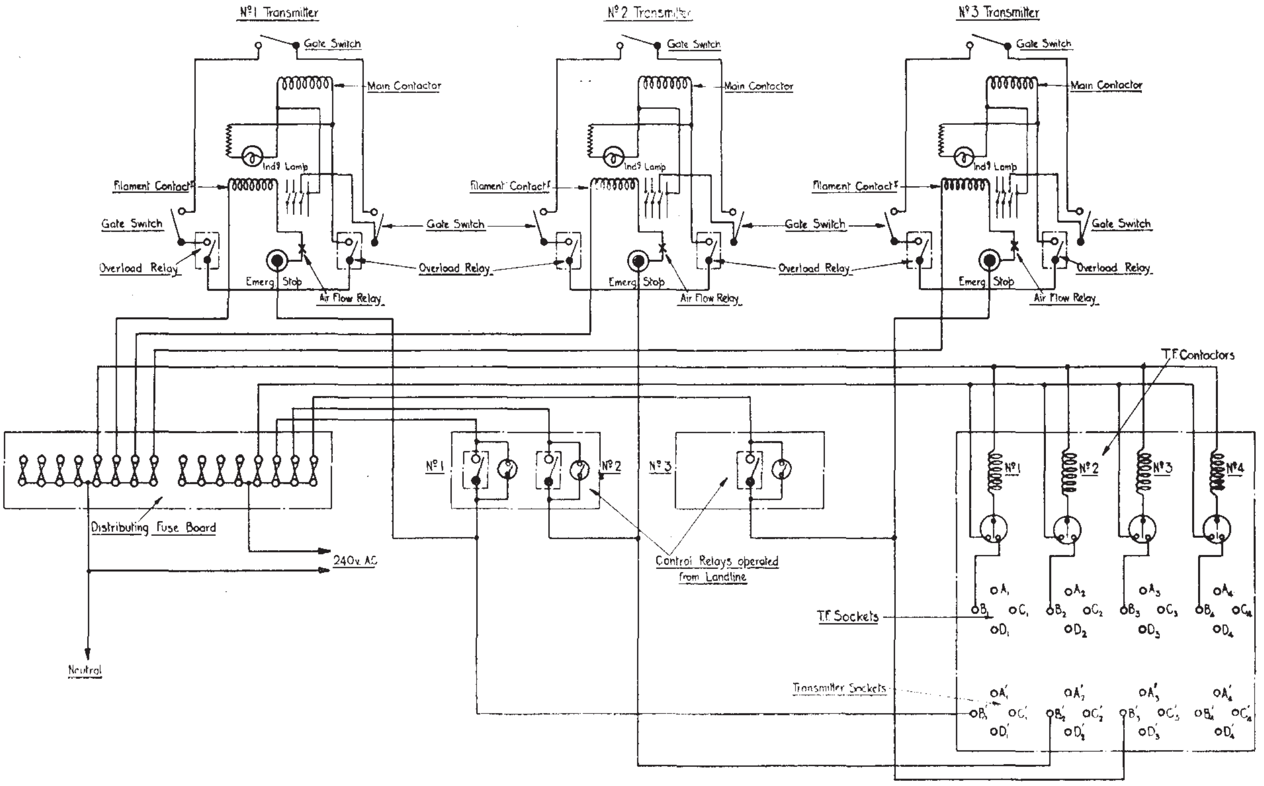


FIG. 12.—TRANSMITTER CONTROL CIRCUIT.

Transmitter Control.—The transmitters may be controlled locally or by landline from Burnham through a series of control relays. The last of these relays closes a 240v. A. C. circuit and operates contactors which make the T.F. supply, main and filament supplies to the particular transmitter, provided that the local contacts on all protective devices are made. The control circuits in which these protective devices are inserted are shown in Fig. **12**. The sockets shown on the bottom right hand corner are fitted on the Tuning-Fork Control Panel (Fig. **7**) from which the output of the T.F. Units is distributed. The plugging-in of a particular T.F. Unit on to a transmitter automatically transfers its controls and other auxiliaries to that particular transmitter.

Landline control of the transmitters is secured by means of diplex circuits, one channel being used for closing the transmitter control circuit and the other for keying. Simplex circuits only are used, communication with Burnham being maintained by means of a direct telephone line; this arrangement materially speeds up circuit changes, etc.

Keying is effected by means of a Creed line relay or Standard B, operated from a Standard B inserted in the line. This relay short circuits the output from the tuning fork controlled oscillator. See Fig. **9**.

It is pleasing to record that the results obtained at Portishead are considerably better than those obtainable at Devizes. The aerial current for a 6 K.W. transmitter has been increased by 50-100%, representing a three to four-fold increase in overall efficiency and the time lost in starting up a transmitter has been reduced from about 45 seconds to 10 seconds.

This saving in starting time appears small, but since a transmitter may be started up as many as a hundred times a day, the saving becomes a real one. Further, if the starting-up of a transmitter is a lengthy operation the tendency is for the receiving station to keep the transmitter running in the interval between messages in order to save delay when traffic comes to hand. The shortening of the starting-up period has reduced this tendency very considerably. Lastly, increased communication facilities between the transmitting and receiving stations have enabled the two stations to co-operate more effectively for the improvement of the service.

ANNUAL REPORT ON POSTS AND TELEGRAPHS, FEDERATED MALAY STATES FOR YEAR 1927.

Telegraphs.—During the year 474,265 telegrams were despatched and 506,248 were delivered, being an increase of 8,749 in the telegrams despatched and a decrease of 3,274 in those delivered. The revenue derived from telegrams was $408,431, of which $305,958 is included in the stamp sales. The revenue shows an increase of $42,852 as compared with 1926. The value of telegrams sent free of charge for other Government departments was $59,554, an increase of $8,217.

Wheatstone high-speed telegraph apparatus was installed in the Kuala Lumpur and Ipoh Post Offices during the year and proved of great assistance in disposing of telegraph traffic between the Federated Malay States and the Straits Settlements.

Telephones.—The number of subscribers to the telephone system on the 31st December, 1927, was 4,003, an increase of 553 as compared with 1926. In addition there were 1,871 extension lines, extension bells, private circuits, private bell or alarm circuits and tell-tale clock circuits maintained by the department, as compared with 1,598 in 1926.

The revenue derived from telephones was $1,062,562, an increase of $158,051 over 1926. The trunk revenue amounted to $317,380, an increase of $40,127 as compared with the previous year.

Four new public telephone exchanges were opened in the course of the year, and on 31st December, 1927, there were 46 public exchanges in the Federated Malay States.

Public call boxes are available at 83 post offices.

On 31st December, 1927, there were 41 applicants awaiting connection to the telephone system; these were very recent applications.

The average number of originated calls per direct exchange line per day was 12.3, an increase of about 2.5 per cent. compared with 1926 (which should have been given as 12.0 not 12.3).

The average total numbers of originated calls per day throughout the Federated Malay States during the year were:—

Local calls	40,200
(increase over 1926, 10%)	
Junction calls	1,000
(increase over 1926, 39%)	
Trunk calls	4,500
(increase over 1926, 17.2%)	
Total originated calls per day ...	45,700
(increase over 1926, 17.6%)	

The approximate total originated telephone traffic during the year was as follows:—

Local calls	11,738,400
Junction calls	292,000
Trunk calls	1,314,000
Total originated traffic during 1927 ...	13,344,400

Development studies were made in a large proportion of the Federated Malay States Telephone Exchange areas during the year for the purpose of estimating equipment and plant requirements.

The preliminary traffic investigations in connection with the design of the new Kuala Lumpur Exchange building were completed during the year.

With regard to the question of " party line " working—referred to in para. 51 of my predecessor's report for 1926—arrangements were made during the year for the installation of a " Rural automatic unit." The equipment is not, however, expected to arrive before the middle of 1928.

Engineering.—On 31st December there were 2,602 miles of telegraph and telephone lines and 21,716 miles of overhead wire in the Federated Malay States, of which 18,483 miles were telephone wires. In addition there were 102 miles of underground cables containing 9,908 miles of wire single line. These figures do not include the poles and lines maintained by the Railway Department for their own use. The Posts and Telegraphs Department also owns and maintains 123 miles of line and 606 miles of wire in Johore. It also maintained in 1927 one and a half miles of pole line for Kedah, 847 miles of wire for Johore, and 24 miles of pole line in the Dindings.

The erection of trunk lines involved heavy work of construction in practically all parts of the country. The progress of new work in Pahang was heavily handicapped by the necessity for almost a complete reconstruction of the whole overhead system due to the damage done by the flood.

Underground cables were considerably extended during the year in all parts of the Federated Malay States, a total additional length of approximately 23 miles of cable, 2,134 miles of single wire, having been laid.

The proposed Malayan Trunk Telephone Cable Scheme was, however, abandoned on financial grounds both by the Federal and Colonial Governments. The rejection of a scheme on which the Engineering Branch had spent so much time and labour, and which was intended to meet trunk requirements for many years, has left the department with considerable leeway to make up as regards the provision of adequate trunk facilities between existing exchanges, so that the extension of the aerial lines to Singapore will not be practicable in the immediate future.

New exchange equipment either additional or replacement was installed at Banting, Bentong, Fraser's Hill, Ipoh, Klang, Kuala Lumpur, Kuala Lipis, Kuantan, Raub, Seremban, Taiping and Tanjong Malim.

At the request of the Governments of Kedah, Kelantan and Trengganu, reports were made by the Senior Engineer of the department on the telegraph and telephone systems in these countries. Following on the report furnished to Kedah, a detailed scheme for the reconstruction of the whole Kedah system was prepared.

Engineering work was somewhat hampered by the shortage of technically trained Asiatic staff. Every endeavour is being made to overcome this shortage by training suitable men in a Departmental Technical School.

Wireless.—Thirty-seven temporary licences for the use of wireless receiving apparatus were issued during the year and four experimental transmitting licences.

The British official news broadcast from the wireless station at Rugby in England, received at Penang Wireless Station and retransmitted from Penang by land line for delivery to the local newspapers on payment of a monthly fee, averaged about 20,000 words a month.

For the purpose of conducting short wave wireless experiments throughout Malaya, two ½ k.w. standard Marconi short wave—C.W. and I.C.W. sets were received in October, but owing to certain faults in the sets it was necessary to obtain various replacements, and these had not been received by the end of the year. It is intended to fit one of these sets on to a motor-lorry, and from this mobile station carry out experiments in various parts of the country. The development of wireless in Malaya will largely depend upon the results of these tests.

Workshop.—The activities of this branch of the department during the year were unprecedented. An outstanding feature of the work was the number of telephone switchboard sections made and installed. The on-costs remained practically the same as in the previous year.

Stores.—The number of different items stocked was 4,180, an increase of 688 as compared with 1926. The value of stores issued and received in 1927 was $2,657,390, compared with $2,183,773 in 1926. Work in the stores was greatly handicapped by inadequate accommodation. The need for more space and for the proposed new store was more strongly felt than ever.

Postal Franking Machines.—During the year postal franking machines were brought into use in the Federated Malay States for the first time, and revenue collected on this account, which would otherwise have been spent on postage stamps, amounted to $2,950.

Co-operative Society.—During the year the Federated Malay States Posts and Telegraphs Co-operative Thrift and Loan Society Limited continued to progress and by the end of the year had a membership of 1,091 as compared with 1,039 on 31st December, 1926, with a total subscribed capital of $246,165. A dividend of 7 per cent. was paid on the 30th June, 1927, as compared with 6 per cent. for the previous year.

Seven hundred and seventy-five loans totalling $198,227 were granted during the period under review, making the total loans granted since the inception of the society 2,567 in number and $617,290 in amount.

It is of interest to note that whilst the number of loans for liquidating debts is decreasing the number of loans for buying land and for building houses is increasing. During the year 119 loans for a total amount of $40,518 were granted for the purchase of land and for the building of houses.

That the society has proved a boon of great value to the members is shown by the fact that during the year 388 loans for a total amount of $71,466 were granted to members on the security of their own subscription credit; such savings would not, in the majority of cases, have been made but for the existence of the society.

Employment of Malays.—The policy of giving preference to Malays in all branches of the department where vacancies occurred was followed wherever possible.

Employment was given to 37 Malays as telephone operators and 31 Malays were engaged as postmen, messengers, peons, mail-runners, etc.

On the engineering side there were at the end of the year 11 Malay apprentice linesmen and nine Malay apprentice or probationer technical subordinates being trained at the Departmental Technical School.

Thirteen Malays with suitable educational qualifications were also engaged as probationer clerks.

Conclusory.—In its endeavour to give the best possible service the department is conscious enough that attainment lags behind the ideal, but postal shortcomings are not entirely departmental and the assistance of the public is earnestly sought in two directions. There is probably no other country in the world where the posting public is so careless about addresses as in Malaya; it is the exception rather than rule to inscribe on the envelope anything fuller than "Richard Doe, Esq., Kuala Lumpur." That may have been explicit enough twenty years ago, but to-day in a town of some hundred thousand inhabitants, and spread over some ninety miles of roads and streets, it is gravely insufficient. Secondly, it should be remembered that English not being the mother tongue of the majority of our telephone operators, wrong connections are as often as not the inevitable result of hurried or imperfect articulation on the part of the calling subscriber.

The following table indicates the growth of the system:—

TELEGRAPH AND TELEPHONE SYSTEM.

Year	Length of overhead line. Miles.	Length of overhead wire. Miles.	Length of under-ground cables. Miles.	Length of wire single line in cables. Miles.
1907	1,341	3,079		
1917	2,276	11,211	26	2,406
1927	2,602	21,716	102	9,908

NOTES & COMMENTS

THE most important happening in the world of communications during the past quarter is perhaps the report of the Imperial Wireless and Cable Conference, which was published on the 27th July. Sir John Gilmore, Secretary for Scotland, was Chairman of the Conference, and Mr. A. M. Samuel, Financial Secretary to the Treasury, was the other representative of this country. Canada, Australia, New Zealand, South Africa, the Irish Free State, India and the Crown Colonies and Protectorates were represented, and Sir Otto Niemeyer and Sir William McLintoch acted as financial advisers to the Conference. The Eastern Telegraph Coy. and its associated companies and Marconi's Wireless Telegraph Co. had declared their intention of forming a combined company on condition that the British Government, as owner of two Atlantic cables and the Beam Radio Stations, and co-partner in the Pacific Cable Board, should agree to merging their interests with those of the companies. After full evidence had been heard and communications duly considered the Conference recommended as follows:—

(1) A Merger Company to be formed to acquire as from April 1st, 1928, all the ordinary shares of the Eastern, Eastern Extension, and Western Telegraph Companies, and all the ordinary and preference shares and debentures (if any) of the Marconi's Wireless Telegraph Co., Ltd.

(2) A Communications Company to be also formed to which the Cable and Marconi Companies will sell as at April 1st, 1928, all their communication assets in exchange for shares. The Communications Company will, therefore, hold all the communication assets of the Cable and Marconi Companies, except in so far as they belong to the subsidiary companies in which the Cable and Marconi Companies' holdings are less than 100 per cent. The Communications Company will acquire the holdings of the Cable and Marconi Companies in those communications companies in which the Cable and Marconi Companies' holding is less than 100 per cent. The Communications Company will also acquire the Government cables and hold the lease of the Post Office beam radio stations. The capital of the Communications Company not to exceed at its inception £30,000,000.

(3) *Terms of transfer of the Government's cable and radio beam assets.*—The Communications Company to take over as from April 1st, 1928, the Pacific Cable Board's cables, the West Indian cable and wireless system worked by the Pacific Cable Board, the Imperial Atlantic cables and the lease of the Post Office beam services (including provision for the transfer to the Company of existing staffs) on terms to be arranged.

The beam services to be leased for 25 years at a rental of—

(*a*) a basic sum of £250,000 per annum;

(*b*) as from April 1st, 1931, an addition equivalent to 12 per cent. on any increase in the Company's profits (from communication services) above the standard revenue;

(*c*) a payment of £60,000 to be made in such manner as may be agreed.

The Communications Company to undertake

to meet the annual service of the outstanding debt on the Pacific Cable Board as on April 1st, 1928, and to pay in addition a capital sum of £517,000 for the Pacific cables, together with interest at 5 per cent. as from April 1st, 1928; to pay £300,000 for the West Indian cable and £450,000 for the Imperial cables.

The rental payable by the Communications Company and the service of the Pacific Cable Board debt will be guaranteed by the Merger Company.

(4) *Direction and management of the undertakings concerned.*—The Board of Directors of the Merger Company, the Communications Company, the Cable and Marconi Companies will be identical. Two of the directors, one of whom shall be chairman of the Communications Company, to be persons approved by His Majesty's Government on the suggestion of the Cable Companies.

(5) *Revenues of the Communications Company.*—A standard net revenue of £1,865,000 (exclusive of non-telegraph investment revenue) from the Communications Company services to be fixed to the purposes of the Company; all net revenue from communication service in excess of that sum to go as to 50 per cent. to the Company, and as to 50 per cent. to reduction of rates or such other purpose as the Advisory Committee (see recommendation 6) may approve. If additional capital expenditure is incurred by the Communications Company in relation to traffic, there shall be added to the above initial standard revenue an appropriate charge for interest at such rate as may later be agreed.

(6) *Control by the Governments concerned.*—The Communications Company to consult, with regard to questions of policy, including any alteration of rates, an Advisory Committee, which the Conference suggests should include representatives of the Governments participating in this Conference, to whom representatives of other parts of the Empire may be added as required from time to time with the approval of the Governments concerned. No increases of rates prevailing at the date of the formation of the Communications Company are to be made except with the assent of the Advisory Committee.

(7) *Additional safeguards and conditions.*—It is to be agreed: (*a*) that British control of all the Companies must be guaranteed; (*b*) that the Governments may assume control of the cable and wireless systems in time of war or other national emergency; (*c*) that the fighting services are entitled to build and work cable or wireless stations for their own purposes, but not for commercial purposes.

(8) *Telephone services.*—The Post Office in London will reserve the right to conduct the external telephone services of Great Britain, but will agree with the Company the terms on which it will have the right to use the Company's wireless stations, or portions thereof, for telephone purposes.

After an appreciatory comment on the value of the Journal to colonial subscribers, Mr. G. W. Heugh, of the engineering branch, Cape Town, gives an amusing account of the difficulties they are experiencing in erecting a line to a new very rich diamond field. Labour is very difficult to obtain for the erection of poles; the men all wish to dig certainly, but in the wrong places; even those who are persuaded to stick to the job carefully sift the soil and toss it in the air to see if they have any luck!

We commend the following letter to the attention of engineering firms who may be considering the extension of their advertising field and are still in doubt as to the best organ in which to extol the claims of their wares. Mr. Turner's advertisement was one dealing with combined voltmeter and milliampèremeter, which is known as the Detector, No. 4:—

Chiltern Works,
55/73, Totteridge Avenue,
High Wycombe, Bucks.
July 5th, 1928.

The Managing Editor,
Post Office Electrical Engineers' Journal,
Alder House, Aldersgate Street,
London, E.C.1.

Dear Sir,

It may interest you to know that my advertisement, which was inserted once in your Journal recently, brought more *orders* than any other advertisement I have had, and enquiries are still coming in from it.

Yours faithfully,
ERNEST TURNER,
per E. GOOD.

We have been asked by Lieut-Col. C. B. Clay to announce that it is proposed to hold a dinner of old National Telephone Company's staff, both active and retired, in London during December. Some sixty names have already been received and Col. Clay would be glad to hear from any men with the above qualifications who would care to attend. His address is Hurst, Sundridge Avenue, Bromley, Kent.

In the *Daily Express* of the 13th ult., the following statement appeared :—

The succession of fires due to defective Post Office cables has caused enormous inconvenience and loss to business firms, and there is widespread curiosity with regard to the real cause of the outbreaks. An electrical expert said to a *Daily Express* representative yesterday: " The fires are due to the antiquated equipment which the Post Office use for their cables.

" The outbreaks are caused by spontaneous combustion. During hot weather, such as we have had this summer, there is a constant danger of fires, which can only be overcome by installing modern equipment.

" The Post Office are afraid to spend the necessary money to bring the service up to date, though business men have lost thousands of pounds this week owing to the disorganised telephone service."

We wonder who the electrical expert is that comes forward with this ridiculous explanation. If there be any " sich person," he either does not know what he is talking about or he is deliberately deceiving the public. He belongs, we are afraid, to the second category of witnesses as defined by a well-known public man, who calls a spade a spade. The cables used by the British Post Office—and here we call the Cable Manufacturers to witness—are the finest and most up-to-date in the world.

We regret that owing to the absence in America on official business of Mr. A. E. Stone it is not possible to include a further article on Start-Stop Printing Telegraphs in the present number. It is hoped to continue this series of articles when Mr. Stone returns.

HEADQUARTER'S NOTES.

EXCHANGE DEVELOPMENTS.

The following works have been completed :—

Exchange.	Type.	No. of Lines.
Holborn	New Auto.	9400
Keighley	,,	1280
Lofthouse Gate	,,	100
Llandudno Junc.	,,	140
Old Colwyn	,,	500
Penrhynside	,,	180
Rochdale	,,	2000
Castleton	,,	165
Heywood	,,	365
Littleborough	,,	265
Milnrow	,,	80
Norden	,,	75
Shaw	,,	270
Whitworth	,,	80
Wilpshire	,,	270
Cosham	Auto Extn.	200
Fleetwood	,,	220
Southampton	,,	540
Batley	New Manual	800
Colne	,,	620
East Grinstead	,,	460
Haywards Heath	,,	540
Ealing	Manual Extns.	2050
Hatch End	,,	390
Kingston	,,	780
Liverpool Desk	,,	—
Margate	,,	820
Maryland	,,	1340
St. Albans	,,	440
Wavertree	,,	1040
Weybridge	,,	300
Worthing	,,	860
Armstrong Siddeley	P.A.B.X's	120
Atkinson & Co.	,,	20
Calico Printers	,,	30
Davenports	,,	30
Delta Metal Co.	,,	30
Dunlop Rubber Co.	,,	20
Huntley & Palmer	,,	170
Nairn & Co.	,,	30
Newcastle Elec. Light ...	,,	20
Rochdale Co-op.	,,	150
St. Helens Corporation ...	,,	80
Salford Corporation	,,	30
Shell Mex (Bristol)	,,	30
Southport Corporation ...	,,	100

Orders have been placed for the following works:—

Exchange.	Type.	No. of Lines.
Addiscombe	New Auto	2700
Crewe	,,	840
Hendon	,,	3100
Macaulay	,,	4500
Nantwich	,,	290
Brighton	Auto Extns.	Rearrangement.
Hove	,,	Rearrangement.
Kirkcaldy	,,	540
Portslade	,,	90
Preston	,,	350
Rottingdean	,,	80
Southwick	,,	110
Connah's Quay	New Manual	440
Parkstone	,,	1580
Stanmore	,,	560
Cambridge	Manual Extns.	1480
Ryde	,,	240
Smethwick	,,	580
Streatham	,,	660
Wednesbury	,,	440
West Bromwich	,,	420
Fleetwood Co-op.	P.A.B.X's	20
Martin Walter & Co.	,,	20
Morris Garages (Oxford)	,,	30
Newcastle Elec. Light	,,	20
Outram & Co.	,,	20
Reading Co.-op.	,,	20
Shell Mex (Bristol)	,,	30

LONDON DISTRICT NOTES.

TELEPHONES.

The following figures show the changes in the number of exchange lines, extensions and stations during the three months ending, and the totals at 30th June, 1928:—

	Increase.	Total.
Exchange Lines	6,319	341,821
Extensions	6,823	287,655
Stations	11,987	573,731

EXTERNAL PLANT.

During the same period the changes shown below have occurred in mileage:—

Telegraphs.—A nett decrease in open wire of 4 miles, and a nett increase in underground of 261 miles.

Telephones (Exchange).—A nett decrease in open wire (including Aerial Cable) of 242 miles, and a nett increase in underground of 68,424 miles.

Telephones (Trunk).—A nett decrease in open wire of 23 miles, and a nett increase in underground of 2,013 miles.

Pole Line.—A nett increase of 13 miles, the total to date being 5,868 miles.

Pipe Line.—A nett increase of 136 miles, the total to date being 9,761 miles.

The total single wire mileage at the end of the period under review was:—

Telegraphs	25,475
Telephones (Exchange)	2,303,718
Telephones (Trunk)	73,271
Spare	107,112

EXCHANGE WORKS.

Beckenham Exchange (C.B. No. 10), capacity 8,000 lines, was opened for traffic on July 25th. Sloane and Bermondsey Auto. Exchanges were successfully opened on July 28th and September 1st respectively. Other Automatic Exchanges which are rapidly nearing completion and will be opened before the end of the year are Monument, Western, and Welbeck. The latter Exchange will relieve the Langham Area.

The installation of the following new Manual Exchanges is well in hand and will be completed within the next few months:—Pollards (in the Norbury Area), Chigwell, Rainham, Sutton, Molesey, Tudor (relieving the Mountview Area) and Valentine (for the relief of Ilford).

The opening of Sloane and Bermondsey Auto Exchanges on July 28th and September 1st respectively marks a further important step in the conversion of the London Telephone Area to automatic working.

The Sloane Exchange was opened with an initial capacity of 8,400 lines and the Bermondsey Exchange with 2,600 lines. Both Exchanges were equipped and installed by the Standard Telephone & Cables, Ltd.

The opening of these Exchanges was eminently satisfactory, the number of faults reported as the result in each case of the transfer being practically nil.

MR. A. B. HART.

MR. A. B. HART.

MR. HART who, on 1st November next, will succeed Mr. W. M. France as Staff Engineer in charge of the Lines Section of the Engineer-in-Chief's Office, entered the service of the Post Office at Cambridge on 1st June, 1893; was transferred to the Engineering Department at Cambridge on 1st December, 1896, and came to Headquarters as 3rd Class Clerk on 20th April, 1898. He was promoted 2nd Class Engineer in charge of the Merthyr Tydvil Section on 9th December, 1901. The period following was a strenuous one. There was keen competition with the National Telephone Company in the coal and steel areas, and active development of the telephone system in new territory in Brecknockshire and Herefordshire was in progress. The opening of new exchanges soon made it necessary to shift the headquarters to a more central position at Brecon. Under the general re-organisation of 1904. the section was further enlarged and the headquarters were again removed—this time to Hereford. Even during this busy period, when long hours had to be worked, Mr. Hart found time for fly fishing and golf, with occasional motoring as opportunity offered. The latter two recreations he still enjoys. On 26th September, 1908, Mr. Hart took charge of the Brighton Section as 1st Class Engineer and returned to Headquarters as Staff Engineer, 2nd Class, on 19th December, 1910. His task was to set up an organisation for dealing with the transmission efficiency aspect of line and exchange plant and with this work he has been associated from that time.

During the War, Mr. Hart was responsible for the circuit arrangements in connection with the Submarine Cable communications with France and the General Headquarters of the Expeditionary Forces and for other special cable arrangements, including those for the Grand Fleet. At the termination of the War he visited Cologne in company with the then Engineer-in-Chief, Sir William Slingo, in order to examine the developments which had taken place in Germany during hostilities, particularly in connection with the use of valves as telephone repeaters. In this way he was among the first to re-establish personal contact between the Administrations of the Allies and of Germany. Being peculiarly gifted with a tactful and conciliating personality and a never-failing fund of humour, which has since endeared him to his numerous friends on the Continent, he was particularly fitted for this delicate mission.

As head of the Transmission group, Mr. Hart has been responsible for the many schemes for loading underground cables, of which, as is well known, there has been an enormous development. Probably the outstanding work for which he will be remembered is the development of the long underground cable system, in association with the Telephone Repeater. While loading enabled underground cable conductors to be used for relatively long distances, as, for example, in the case of the London-Liverpool cable, the gauge of conductor had still to be heavy and the number of pairs which could be accommodated in a cable was limited, being only 52 in the case of the cable mentioned. The Telephone Repeater, however, has revolutionised the whole system. Cables containing over 200 pairs of light gauge conductors can be used and the limit of distance has not yet been reached. It is due to the energy and foresight of Mr. Hart that the development of the Repeater system has been pushed forward and has thus kept this Country abreast of the growth of similar systems on the Continent. It is fortunate that he will still be in control of this work, as the Transmission group has been transferred to the Lines Section. Other developments taking place under Mr. Hart's supervision are Carrier Current Telephony, Voice Frequency Telegraphy and the provision of circuits for Photo-Telegraphy.

Mention should also be made of Mr. Hart's work on the Comité Consultatif International des Communications téléphoniques à grande distance, to all the Conferences of which he has been an active and keenly interested delegate since the inception of the Comité in 1923.

MR. F. TANDY.

Mr. F. Tandy.

Mr. F. Tandy retired on the 31st July, 1928, after having held for 17 years the post of Superintending Engineer, South Eastern District.

His services in the Engineering Department commenced in 1891 at the East Dean Repeater Station on its transfer from the Submarine Cable Company to the Post Office. He also served at Llanfairpwllgwyngyll, Anglesey, the Irish Repeater Station. He was promoted, in 1894, 2nd Class Engineer in the Engineer-in-Chief's Office and became a member of the historical Room 90 staff, which included Messrs. W. Brown, J. Chapman, Eden, Hartnell, Kemp, Purves, Stubbs and Tremain. There he took up the investigation and development of new ideas in electrical communication, many of which betrayed marvellous ingenuity.

Among the earliest problems that made exacting demands on the newly-fledged engineer was Pollock's Multiplex Duplex. Another was the 4-wire Telautograph, a fascimile writing apparatus originally of extreme complexity. Although considerable simplification was effected, this apparatus did not attract the customers whose signatures to distant cheques, and documents, etc., it was designed to transmit. It was tried out between London and Paris.

He shared with Mr. J. Chapman the work which came to fruition in the duplexing of Hughes Typeprinting System. He was the initiator of experiments with the oscillograph and his demonstrations of its applicability to the analysis of telephone speech led to the subject being brought prominently before the I.E.E. by the late Sir John Gavey in his presidential address. Mr. Tandy worked on Poulsen's Telegraphone which had been brought to this country from the Paris Exhibition. The Telegraphone produced results similar to those produced by the Dictaphone. By the magnetisation of a steel wire travelling between the electro-magnets of a telephone receiver the speech currents that passed through the receiver were recorded. These currents were reproduced in the receiver—which in turn became the transmitter — when the magnetised wire was caused to retravel between the electromagnets.

He co-operated with Mr. W. Brown in the experiments on the first heavy gauge trunk lines. These wires, erected on the Midland Railway, provided the first long distance telephone service from London to Leeds, Glasgow, Belfast and Dublin. He was similarly associated in the tests over trunk lines between English provincial towns and the Continent.

When the first two C.B. Switchboards came from America they arrived in this country in a deplorable state of disrepair. One of them was taken by Mr. Tandy to Cork, restored and installed there for experimental trials between London and Cork over the new heavy gauge trunk lines *via* Belfast. Long distance C.B. working was thus proved to be practicable. He co-operated with Mr. Matthew Cooper in the trials of the earliest form of Air-spaced G.P. Cable for submarine telephony, which had been laid between the Isle of Wight and the Mainland. This cable consisted of a G.P. tube in the walls of which were embedded four equi-spaced wires. It may be mentioned that a similar cable laid across the Irish Sea had to be abandoned because the compression in deep sea caused displacement of the wires and consequent distortion of speech.

He took part in the tests and experiments which preceded the adoption of the Trunk Signalling method devised by Mr. Alexander Moir at Leeds. He was the headquarter's expert responsible for the construction and opening of the original trunk exchanges at Glasgow, Manchester, Birmingham and other places. He was engaged at Headquarters in developing Common Battery exchanges in London at Carter Lane, Western, Mayfair, etc., and in connection with the introduction of C.B.S. exchanges in the Thames Valley. He was employed in the experiments on the air-spaced cable between London and Elstree upon which the specifications for the London-Birmingham cable were based.

Mr. Tandy did pioneer work in Wireless. He assisted in Preece's magnetic induction experiments at Carnarvon and elsewhere. He assisted both Preece and Gavey in their public lectures at the British Association and the Society of Arts. He co-operated in the early development of the Marconi invention and in the wireless experiments across the Bristol Channel with Mr. J. E. Taylor.

During his 12 years at Headquarters he was promoted 1st Class Engineer (in 1898) and Technical Officer 2nd Class (in 1902). In 1906 he was transferred to the Metropolitan Central District as Assistant Superintending Engineer, and in 1911 was promoted Superintending Engineer at a time when the responsibilities of the P.O. Engineering Department were about to expand enormously. His district has been conspicuous for growth of plant and services, especially the Continental telegraph and telephone services.

On his last day of office the staff of the district presented to him, with many expressions of esteem and respect, a Rice-Kellogg Loud-speaker, a Phillips Mains H.T. Unit, and a walking stick. Next day a representative party called on Mrs. Tandy and presented to her a gold wristlet watch as a souvenir of the relationship which had existed between Mr. Tandy and the staff for so many years.

At the last Local Engineering Whitley Meeting over which Mr. Tandy presided the Vice-Chairman on behalf of the Staff regretted the imminent retirement of Mr. Tandy, and thanked him for all he had done to further the aims of Whitleyism in the S.E. District. It was also stated that the Staff Side fully appreciated Mr. Tandy's sympathetic attitude, the patience which he had shown in connection with all matters brought forward for discussion, and the invariably tactful manner in which he had presented the views of the Official Side and the Department's requirements.

H. L.

MR. JAMES SINCLAIR TERRAS, S.E. SOUTH WALES.

MR. JAMES SINCLAIR TERRAS.

MR. TERRAS was born and educated in Glasgow. He entered the service of the National Telephone Company in his native city in 1889 and speedily gained recognition, being appointed inspector in charge at Paisley in 1892. In the following year he was promoted District Manager at Galashiels and again in 1896 at Greenock. In 1904 Mr. Terras followed the example of many of his countrymen and crossed the border when he received the district managership at Reading. He was promoted to District Engineer, Birmingham, in 1909, and when the inventory work was started in connection with the transfer of the Company's plant to the P.O. he was placed in charge of one of the divisions. He came over to the Department in 1912 as Executive Engineer, Birmingham, but was promoted next year to Preston as Assistant Superintending Engineer of the North Western District. He has now succeeded Mr. H. Wilson at Cardiff in charge of the South Wales District.

Mr. Terras has had a wide and varied experience. In the early days at Greenock he designed and carried out the original underground system of that town which was one of the first municipalities to afford facilities for underground work in the streets. Since he went to Preston, he has been closely associated with the installation and maintenance of automatics in the areas of Accrington, Blackburn and Fleetwood. Throughout his career he has been keenly interested in the technical education and training of the staff, and has studied the economics of P.O. administration with a continual eye upon the reduction of costs. His recreations now are walking and music, but in his youth he was a keen oarsman. He goes to Cardiff with the best wishes of the staff at Preston and district.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS.

Provisional Programmes, 1928-9.

LONDON CENTRE.

1928.
9 Oct. W. J. BAILEY.
"Chairman's Address."
13 Nov. H. G. S. PECK, B.Sc.
"The Director Exchange in Practice."
11 Dec. E. J. WOODS.
"The Main Underground Trunk Cable System of the British Isles."

1929.
8 Jan. A. J. GILL.
"Telephonic Communication by means of Short Waves."
12 Feb. A. J. ALDRIDGE.
"Sound Measurement."
12 Mar. I. H. JENKINS.
"Circuit Design."
14 May W. G. RADLEY.
"X-Rays and the Structure of some Engineering Materials."

Reserves: Capt. TIMMIS.
"Carrier Current Telephony."
R. W. PALMER.
"The Measurement of Relay Times."

Informal Meetings.

1928.
25 Oct. P. J. RIDD.
"Chairman's Address."
27 Nov. J. COWIE.
"Staff: Character judging. Talk on Personal Characteristics."

1929.
22 Jan. H. E. MORRISH.
"Laying, Jointing and Testing of Cables."
26 Feb. W. DOLTON.
"Wireless. Inspection of Amateur Stations."
26 Mar. D. C. MADDOCKS.
"Tandem Exchange & C.C.I. Working."
H. T. BINES.
"Holborn Automatic Exchange."
23 Apl. B. LYNN.
"Ecclectic Junctions."

NORTHERN CENTRE.

1928.
9 Aug. Summer Outing.
17 Oct. J. R. Edwards.
"Output of the Worker and Methods of increasing it."
21 Nov. T. Pearson.
"Organisation of Advice Note Work."
12 Dec. Thos. Davidson.
"Underground Breakdown Organisation."
1929.
9 Jan. E. J. Woods. *(E.-in-C.O.).*
"The Main Underground Trunk Cable System of the British Isles."
20 Feb. C. E. Worthington.
"Underground Line Construction with suggestions for reducing Costs."
20 Mar. F. W. Gaskins.
"The Cabling of the Tyne Bridge."

NORTH EASTERN CENTRE.

1928.
9 Oct. A. S. Renshaw. *(E.-in-C.O.).*
"Some general considerations relating to Clerical Organisation of Engineering Department."
13 Nov. J. J. Edwards, B.Sc.(Eng.), A.C.G.I., D.I.C.
"Modern Electrical Illumination."
11 Dec. C. Wood.
"Secondary Cells as used in the P.O."
1929.
8 Jan. E. J. Woods, A.M.I.E.E. *(E.-in-C.O.).*
"Main Underground Trunk Cable System of the British Isles."
12 Feb. R. G. DeWardt, A.M.I.E.E.
"Grimsby Beam Radio."
12 Mar. H. McLean.
"P.O. Engineering Inspectors."

NORTH WESTERN CENTRE.

W. S. Procter. *(Technical Section).*
"Cordless B Key-sending positions in Director and Non-Director Areas."
H. Horrocks. *(Rochdale).*
"Petrol Engines, with special reference to the Electrical Circuits."
C. Coward. *(Preston).*
"Unit Construction and Maintenance Costs (External) From fundamentals."
T. E. Tootell. *(Preston).*
"Some Notes on the Maintenance of Machine Telegraphs."
E. J. Woods. *(E.-in-C.O.).*
"The Main Underground Trunk Cable System of the British Isles."
F. G. C. Baldwin. *(Northern Centre).*
"The Early Development of Telephonic Switching."

SOUTH LANCS. CENTRE.

1928.
15 Oct. Chairman's Address.
Film—"Wires across the Sea."
12 Nov. H. P. Clyma.
"Automatic Telephony—Trunk and Grading."
10 Dec. H. M. Turner.
"Secondary Cells."
1929.
14 Jan. E. J. Woods. *(E.-in-C.O.).*
"The Main Underground Trunk Cable System of the British Isles."
11 Feb. R. G. DeWardt. *(N.E. Centre).*
"Wireless Beam System."
11 Mar. *To be decided later.*
8 Apl. A. J. Aldridge. *(E.-in-C.O.).*
"Sound Measurement."

NORTH MIDLAND CENTRE.

1928.
Oct. Mr. Thatcher.
"Auxiliary Power Plant Services; Sheffield Auto. Area."
Nov. J. Wyatt.
"Fundamental Lay-out Claims."
Dec. Capt. H. G. Tissington.
"Time Tests and Construction Costs."
1929.
Jan. E. J. Woods. *(E.-in-C.O.).*
"The Main Underground Trunk Cable System of the British Isles."
Feb. R. Towers.
"Skegness Radio Station."
Mar. Mr. Warrand.
"Main and Local Lines. Plans and Records."

SOUTH MIDLAND CENTRE.

1928.
3 Oct. J. E. Taylor, M.I.E.E.
"Chairman's Address."
7 Nov. H. W. Peck.
"Notes and Comments on Records."
5 Dec. F. D. Traviss.
"Secondary Cell Maintenance."
1929.
2 Jan. F. R. Luckham.
"The Training of Youths."
6 Feb. E. J. Woods, A.M.I.E.E. *(E.in-C.O.).*
"The Main Underground Trunk Cable System of the British Isles."
6 Mar. P. J. Campbell.
"Four Wire Telephone Repeaters and associated Circuits."

NORTH WALES CENTRE.

1928.
10 Oct. Capt. J. Oxon, M.I.E.E
"Secondary Cells."
14 Nov. A. S. Renshaw. *(E.-in-C.O.).*
"Some general considerations relating to the Clerical Organisation of the Engineering Department."
11 Dec. Exhibition of Technical Films, including the film "Voices Across the Sea."
1929.
10 Jan. Capt. Cave-Browne-Cave.
"Modern Views as to the structure of Matter" (with visit to Fordrough Lane, Birmingham Testing Branch and Repair Factory).
6 Feb. E. J. Jarrett.
"Director Working."
27 Feb. E. J. Woods, A.M.I.E.E. *(E.-in-C.O.).*
"The Main Underground Trunk Cable System of the British Isles."
19 Mar. E. J. Prichard.
"Telephone Repeaters."

SOUTH WALES CENTRE.

1928.
8 Oct. E. H. Jaynes.
"Photo Telegraphy and Television."
12 Nov. E. J. Woods, A.M.I.E.E. *(E.-in-C.O.).*
"The Main Underground Trunk Cable System of the British Isles."
3 Dec. H. C. Gunton. *(E.-in-C.O.).*
"Recent Developments in Power Engineering in the Post Office."
1929.
14 Jan. G. E. J. Jacobs.
"Repeater Station Working."
11 Feb. E. S. Ritter. *(E.-in-C.O.).*
"Picture Telegraphy."
Mar. R. T. Robinson. *(E.-in-C.O.).*
"Motor Transport in the Engineering Department."

SOUTH WESTERN CENTRE.

1928.	
9 Oct.	Chairman's Address. Cinematograph Film, " Voices across the Sea."
13 Nov.	E. J. Woods. *(E.-in-C.O.).* " The Main Underground Trunk Cable System of the British Isles."
11 Dec.	Messrs. Came and Treglown. " Automatic Exchange Maintenance."
1929.	
9 Jan.	I. H. Jenkins. *(E.-in-C.O.).* " Circuit Design."
12 Feb.	J. Radford. *(E.-in-C.O.).* " Automatic Exchange Design."
12 Mar.	R. F. Soper. " Some Aspects of Trench Restoration with a view to the avoidance of claims for consequential damage."

EASTERN CENTRE.

1928.	
11 Sept.	Film, " Voices across the Sea," followed by certain slides on Submarine Cables about which Mr. J. F. Lamb will speak.
23 Oct.	A. S. Renshaw. *(E.-in-C.O.).* " Some General Considerations relating to the Organisation of the Engineering Department."
20 Nov.	E. J. Woods, A.M.I.E.E. *(E.-in-C.O.).* " The Main Underground Trunk Cable System of the British Isles."
Dec.	*Being arranged.*
1929.	
Jan.	*Being arranged.* R. J. Hines. " Some Phases of Automatic Telephony."

Owing to want of space, Scotland East and West and North Ireland Centres have been held over until next issue.

SILVER MEDALISTS, 1926-27.

Mr. J. Innes, Edinburgh.
I.P.O.E.E. Senior Silver Medalist, 1926-27.

Mr. B. Millar, Newcastle-on-Tyne.
I.P.O.E.E. Junior Silver Medalist, 1926-7.

LOCAL CENTRE NOTES.

NORTH MIDLAND DISTRICT.

The promotion of Mr. Gomersall to Deputy Superintending Engineer, London, was made the occasion in the North Midland District of a presentation to him by the Staff of a gold watch, suitably engraved, to mark the appreciation in which he was held. In acknowledging the gift Mr. Gomersall stated that the nine years spent in the District were years of great activity and some difficulty and the success achieved had only been made possible by the zeal which was common to all grades and the friendly co-operation which was shown on all sides. He would always retain the warmest regard for the North Midland District from which he parted with great regret.

BOOK REVIEWS.

Pitman's Technical Dictionary. To be issued in about 36 Parts, each part containing about 64 pp., size 9¾ in. by 7½ in.; price 2/6 net. Sir Isaac Pitman & Sons, Ltd., London, W.2.

The complete issue will contain nearly 2,000,000 words, covering engineering and industrial science terms in seven languages: English, French, Spanish, Italian, Portuguese, Russian and German. The dictionary is edited by Ernest Slater, M.I.E.E., M.I.Mech.E. The first part was issued at the end of April, the others to follow fortnightly.

The A.T.M. " Universal" Duplex Unit R 86. The A.T.M. Company has issued a bulletin describing the above unit, which has been designed for fitting on duplex telegraph circuits and provides a means of readily providing terminal apparatus ready for service on practically any length of line. The unit is enclosed in a wooden case, similar in make-up to many wireless cases now on the market, and is completely wired up with spring sets for relay fixing and is fitted with testing facilities for measuring the characteristic resistance, the conductor resistance and the insulation resistance of the line. The set can be used for either Up or Down Station working and two units, side by side, can be quickly utilised by cross-connecting as a duplex repeater.

Strowger Automatic Telephones (Automatic Telephones Co. Bulletin No. 300).

The Automatic Telephone Manufacturing Co. are to be congratulated on this production, which is handsomely bound and combines a delightful colour scheme with interesting reading matter. The Bulletin gives a general description of Strowger working including the Director system. The value of the Bulletin is enhanced by the inclusion of a list of some of the Public Exchanges throughout the world using Strowger equipment, and it is extremely informative.

The illustration of the Holborn Exchange equipment will be of immediate interest to readers of the Journal. It is interesting to note that there are over four million Strowger Automatic Telephones installed or under construction throughout the world.

We have received from the Weidmannsche Buckhandlung Co., of Berlin, the following:—

(*a*) " Zur Theorie des Fernsprechrerkehrs." By K. Frei.

(*b*) " Die Ausbreitung der Elektromagnetishen Wellen." By Dr. Alfred Sacklowski.

(*c*) " French-German Dictionary for Long Distance Telephone Traffic." By Albert Lang.

These are volumes I., II. and III. respectively of a series of short treatises on various phases of the electrical industry of which the general editor is F. Moench.

(*a*) This is a book on telephone traffic and treats the matter, of course, from a theoretical standpoint, and from this point of view goes back to first principle. Besides dealing with the theories most favoured in Germany, the author includes criticisms of workers of other countries. Besides the ordinary telephone traffic problems he includes chapters on waiting times as experienced with such systems as the Western Electric rotary and also with the distribution of call durations.

(*b*) This book is a review of existing literature on the propagation of electro magnetic waves.

At the end, a bibliography with 474 entries is given and many of these are referred to in the text.

(*c*) This dictionary being only in French and German is of comparatively little direct interest in this country. It does, however, appear to give very completely, both in French-German and German-French the main terms used in telephone transmission.

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

PROMOTIONS.

Name.	Grade.	Promoted to	Date.
Terras, J. S.	Asst. Suptg. Engineer, N.W. Dist.	Suptg. Engineer, S. Wales District.	15-8-28
Bullock, A. H.	Executive Engineer, Leicester Section, N.Mid. District.	Assistant Suptg. Engineer, N. Mid. District.	19-8-28
Alexander, R.	Executive Engineer, Edinburgh Inner Section, Scot. E. Dist.	Assistant Suptg. Enngineer, N.E. District.	30-8-28
Baxter, J.	Executive Engineer, Hereford Section, S. Wales District.	Assistant Suptg. Engineer, S.W. Dist.	4-9-28
Halton, R.	Executive Engineer, Technical Section, S. Mid. District.	Assistant Staff Engineer. Lines Section, E.-in-C.-O.	31-8-28
Pink, E. A.	Executive Engineer. Bristol Section, S.W. Dist.	Assistant Staff Engineer, Construction Section, E.-in-C.O.	To be fixed later.
Statters, J. E.	Executive Engineer, Lines Section, E-in-C.O.	Assistant Staff Engineer, Lines Section, E.-in-C.O.	1-11-28
Lucas, J. G.	Executive Engineer, Telephone Section, E-in-C.O.	Assistant Staff Engineer, Telephone Section, E.-in-C.O.	1-8-28
Reid, Capt. F., M.C.	Executive Engineer, Designs. Section, E-in-C.O.	Assistant Staff Engineer, Designs Section, E.-in-C.O.	1-12-28
Cruickshank, W.	Executive Engineer, Research Section, E-in-C.O.	Assistant Staff Engineer, Research Section, E.-in-C.O.	1-8-28
Hansford, R. V., D.Sc.	Executive Engineer, Radio Section, E-in-C.O.	Assistant Staff Engineer, Radio Section, E.-in-C.O.	1-8-28
Dolton, W.	Assistant Engineer, Technical Section, London District.	Executive Engineer, Technical Section, London District.	1-8-28
Ryder, W. V.	Assistant Engineer, Lincoln Section, N.E. District.	Executive Engineer, Headquarters to be fixed later.	26-8-28
Mitton, F. E.	Assistant Engineer, Centre External Section, London Dist.	Executive Engineer, North West External Section London District.	1-8-28
Pratt, A. J.	Assistant Engineer, Technical Section, S. Lancs. District.	Executive Engineer Technical Section, N. Wales District.	To be fixed later.
Duathorne, H. R. J.	Assistant Engineer, Technical Section, N. District.	Executive Engineer, Hereford Sectn., S. Wales District.	To be fixed later.
Deane, W.	Assistant Engineer, City Internal Section, London District.	Executive Engineer, Leicester Section, N. Mid. District.	19-8-28
Peacock, C. T.	Assistant Engineer, Designs Section, E-in-C.O.	Executive Engineer, Designs Section, E.-in-C.O.	1-8-28
Harding, R. W.	Assistant Engineer, Lines Section, E-in-C.O.	Executive Engineer, Technical Section, S. Mid. District.	To be fixed later.
Plymen, H. S.	Assistant Engineer, Telephone Section, E-in-C.O.	Executive Engineer, Lines Section, E.-in-C.O.	1-11-28
Scutt, W. D.	Assistant Engineer, Telephone Section, E.-in-C.O.	Executive Engineer, Telephone Section, E.-in-C..O	1-8-28
Carter, Major H.	Assist. Engineer, Construction Section, E-in-C.O.	Executive Engineer, Construction Section, E.-in-C.O.	1-8-28
Struthers, G. A.	Assistant Engineer, Radio Section, E-in-C.O.	Executive Engineer, Bodmin Radio.	18-8-28
Walmsley, T.	Assistant Engineer, Radio Section, E-in-C.O.	Executive Engineer, Radio Section, E.-in-C.O.	1-8-28
Smith, Albert	S.W.I., Testing Bch.	Inspector, Testing Bch.	6-4-28
Smith, Arthur,	S.W.I., Testing Bch.	Inspector, Testing Bch.	5-8-28
Noble, J.	S.W.I., Scotland West.	Inspector, Scot. West.	16-4-28
Burn, T.	S.W.I., Scotland West.	Inspector, Scot. West.	To be fixed later.
Thomson, J.	S.W.I., Scotland West.	Inspector, Scot. West.	25-8-28

RETIREMENTS.

Name.	Districts.	Grade.	Date.
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Allen, F. J.	,,	E.-in-C.O.	30-6-28
Wood, A. H.	,,	E.-in-C.O.	30-7-28
Morris, A. C.	Assistant Engineer.	N. Mid. District.	1-6-28
Copeland, F. H.	,,	S. Wales District.	25-6-28
Broomhead, H. H.	,,	N. Ireland District.	20-8-28
Bradshaw, A. R.	Inspector.	N. Wales District (resgd.)	1-8-28
Folkard, G. F.	,,	Ldn. Engineering Dist. (resgd.)	8-8-28
Tandy, F.	Suptg. Engineer,	S.E. District.	31-7-28
Wilson, H.	,,	S. Wales District.	31-7-28

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Name.	District.	Grade.	Date.
Sunderland, M.	N.W. District.	Inspector.	9-8-28

TRANSFERS

Name.	Rank.	From	To	Date.
Mathew, K. R.	Inspector.	Scot. E. District.	Scot. West District.	3-6-28
Hall, H.	,,	,,	,,	3-6-28
Michaelsen, G. E. F.	,,	S. Lancs.	S. West District.	17-6-28

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Oldfield, G.	Acting Staff Officer, E.-in-C.O.	Staff Officer, E.-in-C.O.	17-7-28
Ramsay, J.	Executive Officer, E.-in-C.O.	Acting Staff Officer, E.-in-C.O.	17-7-28

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Boddington, M.F.G.	Principal Clerk, E.-in-C.O.	Retirement.	30-6-28
Jelf, F. H.	Higher Clerical Officer, London.	Death.	13-6-28

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	Electrical Safety Code	Bureau of Standards, U.S. Dept. of Commerce.
875	Textbook of Telegraphy	A. E. Stone.

THE
Post Office Electrical Engineers' Journal

A VOICE FREQUENCY MULTI-CHANNEL TELEGRAPH SYSTEM.

J. M. Owen and J. A. S. Martin.

VOICE Frequency Telegraphy, as the name implies, is a system of Telegraphy worked with alternating currents and at frequencies within the Voice Range. For a number of years the question of telegraph transmission by means of such a system has been considered by telegraph engineers, but until recently no great progress was made.

The great extension of loaded underground cables in this country and the completion of the main underground routes have emphasised the need for some new system of telegraphy which would facilitate successful working of telegraphs and telephones in the same cable.

Although there is a fairly comprehensive telegraph underground network in this country, a considerable number of telegraph circuits are accommodated in the new trunk cables. The question of maintaining the greatest degree of non-interference between the two systems is therefore a matter of the utmost importance. At present the telegraphs are worked on unloaded pairs and the power used, as compared with that on a telephone circuit, is considerable and makes he conditions very exacting.

Further, in the light of present developments t would not appear to the authors to be economical to provide separate unloaded pairs for telegraph purposes except in short cables, as it is now possible to use loaded pairs for multi-channel Voice Frequency working or alternatively for simultaneous telegraph and telephone working.

Under these conditions the cross-talk between the telegraph and telephone circuits will be of the same order of magnitude as that permissible between normal telephone circuits.

At present there are three known methods of working telegraphs on loaded underground conductors, viz. :—

(*a*) Phantom superposed working.
(*b*) Sub-audio frequency or composited working.
(*c*) Voice Frequency working.

(*a*) This system is adapted for use on the phantom of the two side circuits of a telephone quad. It is the same as that normally used in superposed working with the exception that special arrangements by means of smoothing and impulse equalising circuits are made, whereby the telegraph interference in the telephone circuits is reduced or superposed entirely. For long distance working arrangements must be made to bye-pass the D.C. telegraph signals at the telephone repeater stations. This system has its disadvantages, since the telegraph circuit—when loaded phantom circuits are used—is replacing a telephone circuit, and, further, the speed of the telegraph circuit is limited, owing to the use of the various smoothing devices. This system could be employed where magneto signalling is used on the telephone loops.

(*b*) Sub-Audio Frequency working is a system in which high and low pass filters are used. The telegraph and telephone circuits work on the same pair. The low pass filter cuts off all frequencies above 40 cycles in the telegraph circuit (*i.e.*, an equivalent Wheatstone speed of approximately 100 words per minute), and the high pass filter prevents the telegraph signals from entering the telephone circuit. This arrangement gives a working telegraph speed of about 70 words per minute.

This system is certainly economical, but the maximum speed of working is comparatively low. It will, however, be invaluable on minor circuits. This system cannot be employed where magneto signalling is used on the telephone circuit. Arrangements must be made to use, say, 500 cycle ringing.

(*c*) Voice Frequency Multi-Channel telegraphy is a system working on a principle similar to that of a four-wire repeated telephone circuit, and may have six or more channels each way, each of which is capable of working at approximately 100 words per minute.

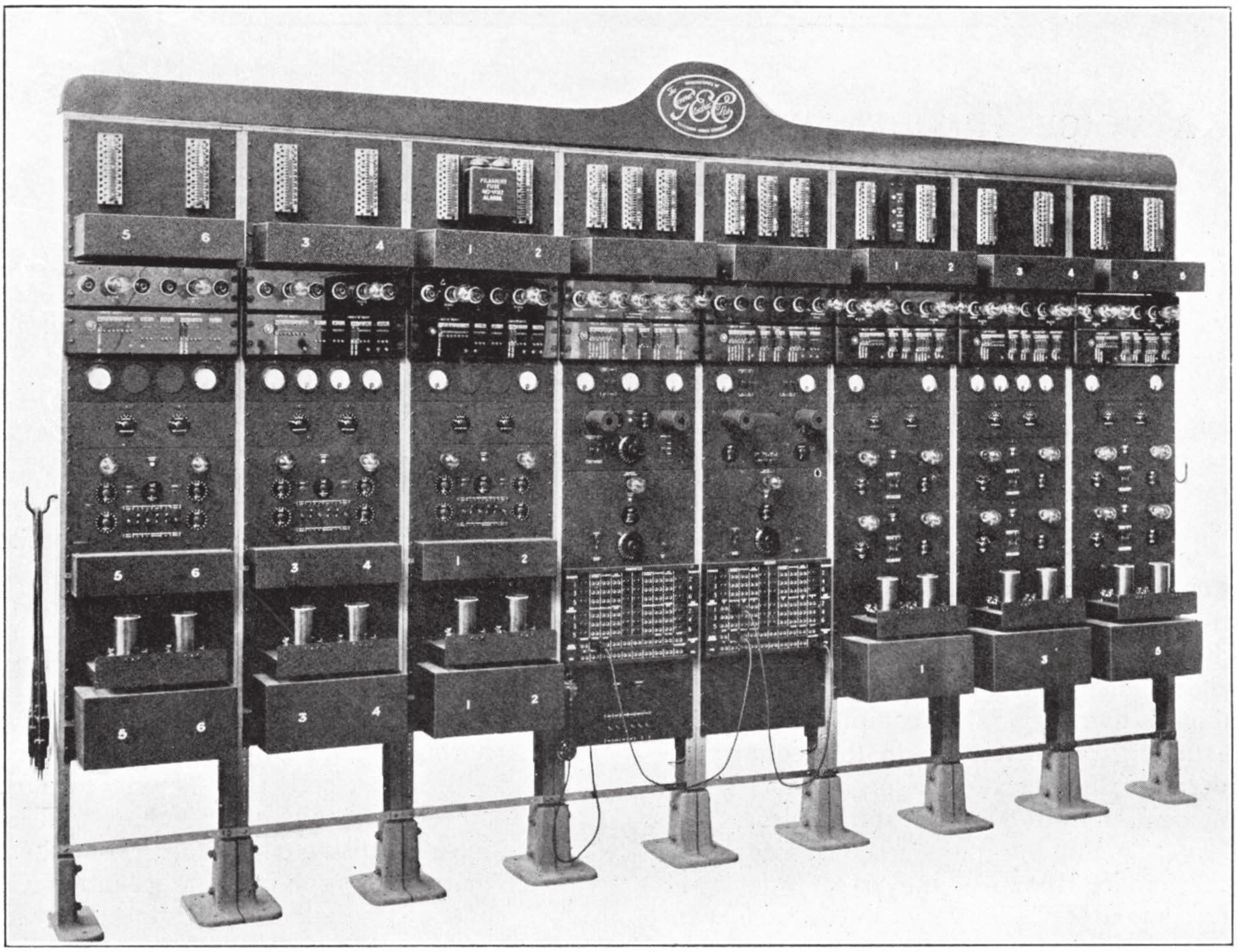

Fig. 1.—Front view of Complete Installation.

It follows, therefore, that any telegraph system which does not require a speed in excess of this can be worked on any of the channels. Since this system works on a telephone principle as regards power, etc., it can be readily appreciated that the interference resulting in other circuits will not exceed that normally met with between telephone circuits in a loaded underground cable.

Furthermore, as the ordinary telephone repeaters are used, this system can be worked on any telephone circuit normally adapted for four-wire working. Although this system makes use of a circuit that could be used for telephone purposes it must be remembered that six separate high speed circuits are provided for telegraph working.

It is proposed here to deal with a Voice Frequency System developed by the General Electric Coy. with the co-operation of the Post Office.

General Principles.

In this system oscillations are generated in six oscillating circuits by means of valve controlled tuning forks[*] at $\omega = 2500$, 4000, 5500, 7000, 8500 and 10,000 respectively. These frequencies are applied to the primary windings of six input transformers through the local contacts of telegraph relays, the secondary windings being joined in series and connected to the grid of a common transmitting amplifying valve (see Fig. **7**). The operation of one or all of the telegraph relays, which are actuated by D.C. signals from the telegraph office, impresses oscillations on the grid of the common transmitting amplifying valve. Amplified oscillations are passed out to line and received at the distant end on the grid of a common receiving amplifying valve. From the anode of this valve, the amplified oscillations are passed to six band-pass filters connected in parallel. After passing through their respective filters the oscillations are again amplified, the amplified signals being rectified by another valve. The rectified signals operate a telegraph relay, signals being passed to the telegraph office by means of a local battery and the tongue of the relay.

The complete installation is made up of eight bays, each 7′ 7½″ high and 1′ 8¼″ wide. Two transmitting channels occupy one bay, the six channels therefore being accommodated on three bays. Similarly, two receiving channels occupy one bay, the six occupying three bays. Separate bays are provided for the common transmitting amplifier and the common receiving amplifier, remaining space on both bays being occupied by subsidiary apparatus which will be described later.

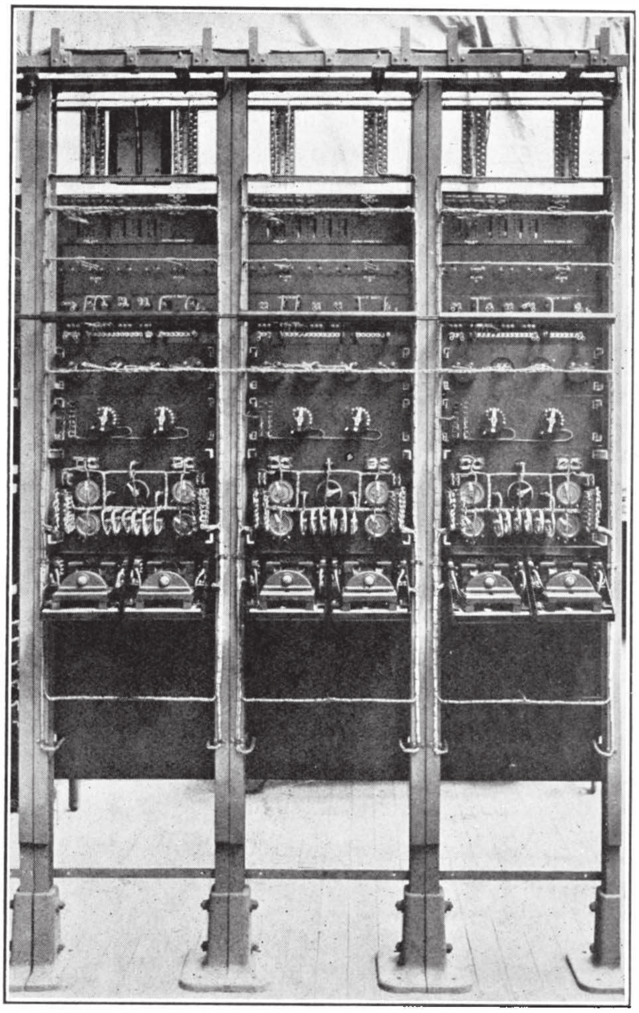

Fig. **2**.—Back view of Transmitting Bays.

The telegraph relays are of the P.O. Standard " B " type fitted with flexible spring tongues. This type of relay prevents chattering at the relay contacts. Contact pillars and springs are fitted to enable the relays to be slipped in and out at will and so permit changes of relay to be made quickly.

Transmitting Bay.—Fig. **2** shows a back view of the three sending bays with the covers removed. Each transmitting bay consists of two transmitting units. The upper part of the bay is occupied by connection strips, resistance spools and alarm relays, battery lamps and battery panel complete with fuse mountings.

The fittings for the telegraph relays, together with subsidiary apparatus are fitted on the lower portion of the bay. See left of Fig. **1**. The centre of the bay carries the telegraph galvanometers and rheostats for controlling the current received from the telegraph office. On this panel we also have the valves, together with their battery cut-off and ammeter keys, and two keys by means of which the telegraph relays are operated for test purposes. A filament alarm lamp is fitted above the battery and ammeter keys, and an alarm lamp is fitted above each relay test key as the operation of that key disconnects the telegraph office from the relay. In addition to the telegraph galvanometers, the second bay carries an ammeter and milliammeter serving all transmitting bays, in order to measure filament, anode and fork magnetising currents. The tuning forks are mounted on massive brass bases at the back of the bay. They are insulated mechanically by means of Sorbo rubber, each fork being separately electrically screened. Polarisation is effected by an electromagnet. The anode grid and output coils are the same for all frequencies. The supports for the tuning forks are adjustable, as they have to accommodate forks of different lengths according to the frequency required. The fork unit is connected to the circuit by means of plugs and cords, and is therefore easily detachable for test purposes or for replacements. Fig. **3** shows a tuning fork mounting. The necessary condensers for anode and grid coils are fitted on the shelf which carries the fork mounting.

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[*] *Under the patents of Messrs. Eccles and Jordan.*

Control of the magnetising current is effected by a rheostat 0-350 ohms, and by throwing a switch a milliammeter, common to all transmitting bays, is brought into circuit. The valve filaments are heated in series from a 24 volt battery; grid priming is derived from the filament circuit, and a 150 volt battery is used for the plate circuits. The valves used are the P.O. Standard V.T. 25 type.

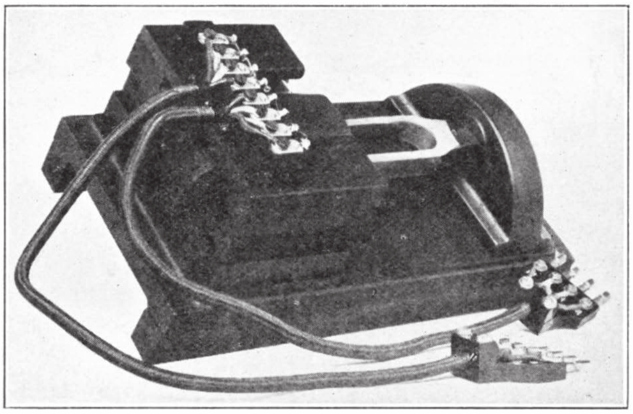

FIG. **3**.—TUNING FORK MOUNTING.

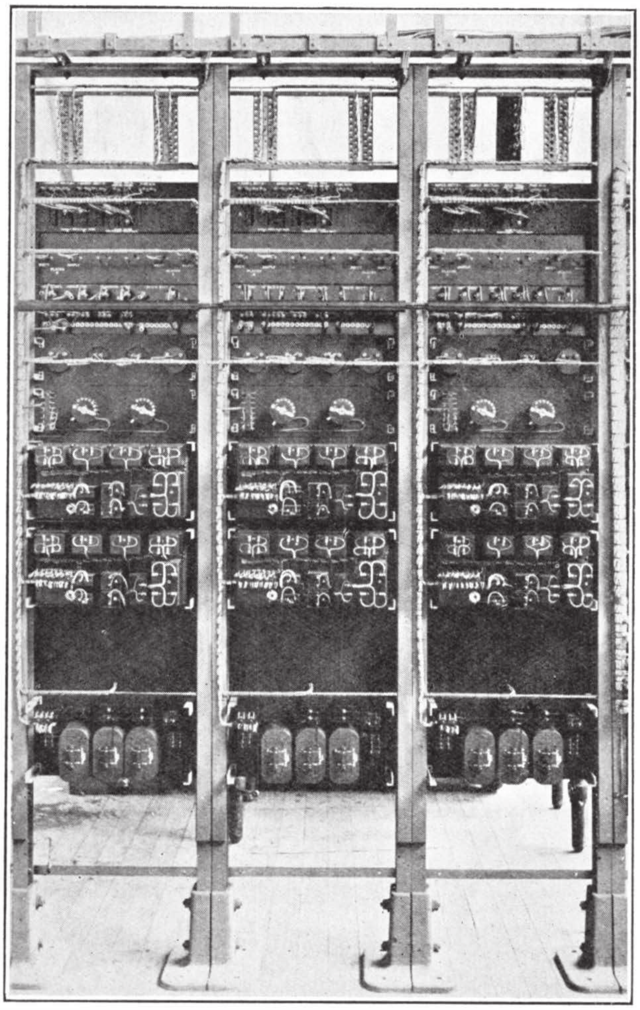

FIG. **4**.—BACK VIEW OF RECEIVING BAYS.

No filters are used at the transmitting end, as the output is sufficiently free from harmonics to permit of transmission direct to the common transmitting amplifier.

Receiving Bay.—Fig. **4** shows a back view with the covers removed.

The receiving bays are similar in design to the transmitting bays, the connection strips, alarm relays, resistance spools, battery resistance lamps, battery panel, telegraph galvanometers and relays occupying similar positions.

Each receiving bay carries two receiving units, each unit consisting of an amplifier and a rectifier, the amplifying valve being an Osram

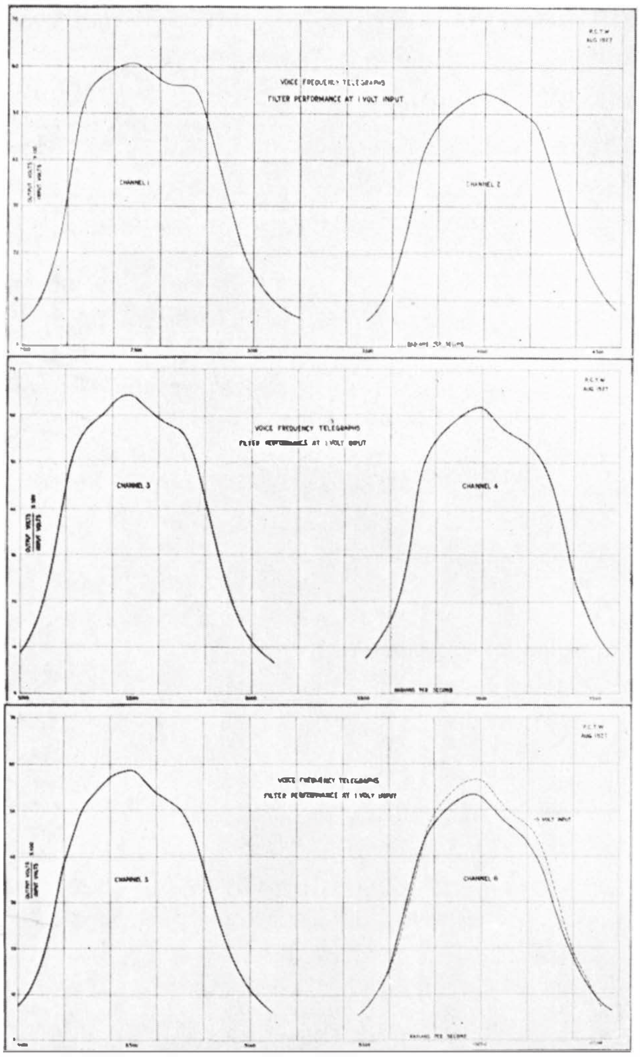

FIG. 5.—FILTER EFFICIENCY CURVES.

L.S.5B, and the rectifier an Osram L.S.5A. See right of Fig. **1**. The filters for the two circuits are fitted at the bottom of the bay, one at the front and the other at the back. The middle of the bay is occupied by the valves and their respective battery and test keys, filter output controls and filament rheostats. As in the case of the transmitting bay, an ammeter and milliammeter are fitted on the second bay, both instruments being common to all receiving bays. Transformers and other subsidiary apparatus are accommodated on the back of the bays. With the exception of the filter, each receiving unit is identical for all channels. The priming for the rectifying valves is supplied from a special 100 volt grid battery which is carried on the back of the frame. A 24 volt positive and negative earthed battery is used for the locals of the telegraph relays. Apart from these the battery arrangements are similar to those of the transmitting bays.

Efficiency curves for the respective band pass filters are shown in Fig. **5**, from which it will be seen that there is no overlapping of the bands.

Common Amplifier Bays.—Fig. **6** shows a back view of the two common amplifier bays.

Both the common transmitting and receiving amplifiers, together with subsidiary apparatus, occupy separate bays and are placed between the

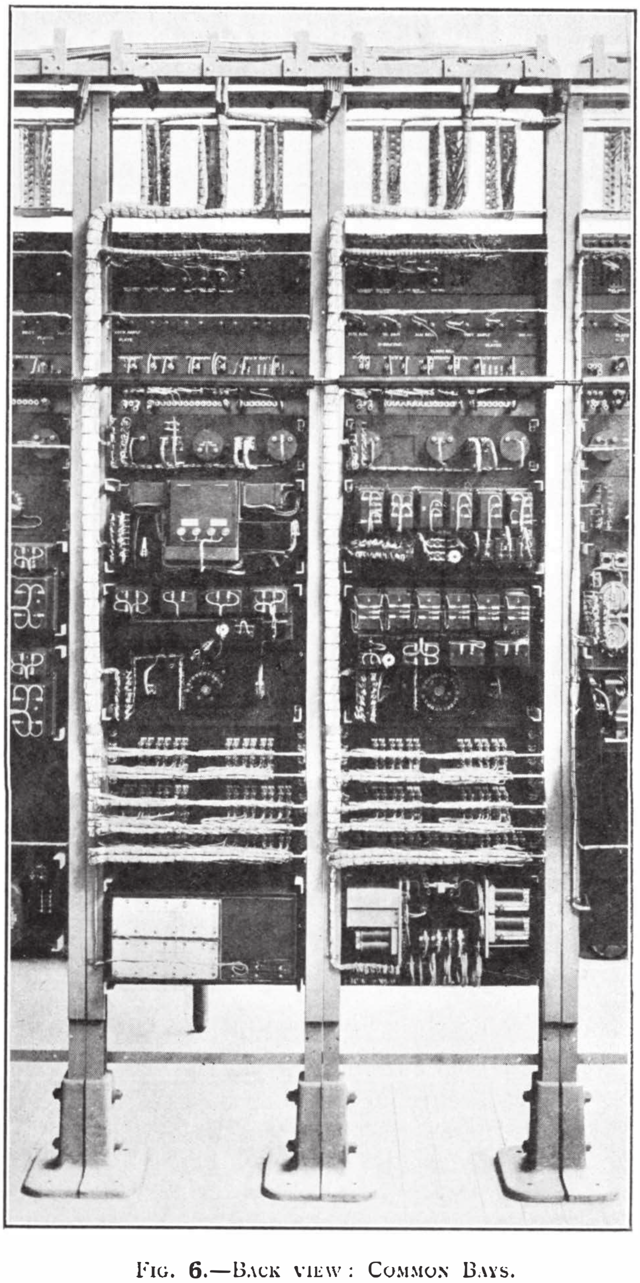

FIG. **6**.—BACK VIEW: COMMON BAYS.

transmitting and receiving bays. As in the case of the other bays, the top is occupied by connection strips, alarm relays battery lamps, battery panel and other minor apparatus. At the bottom of each bay is a series of branching jacks, (See centre bays in Fig. **1**) which in conjunction with a valve voltmeter enables tests and measurements to be made at different parts of the circuit and also provides cross-connecting facilities for the various channels. Below the test jack panel on the left hand bay there is a telephone panel which provides for the termination of two speaker lines, and is similar to that normally fitted on two-wire repeater circuits. One of the telephone circuits is for communication between the terminal voice frequency stations, and is worked on the phantom circuit of the " go " and " return " pairs. The other telephone provides communication with the local telegraph office. The centre of the common transmitting bay is occupied by a simple telegraph test set and an ammeter and milliammeter which are common to both bays. On this bay there is also a calibrated two valve testing amplifier, below which is the common transmitting amplifying valve together with battery keys and adjusting apparatus. A graduated artificial cable, calibrated in T.U.'s is provided for adjustment of the power level and to control the output. The centre of the receiving bay is occupied by a battery voltage testing set, and a valve voltmeter (Tinsley pattern) for measuring A.C. voltages. Below these are the common receiving amplifier valve and battery keys together with a filament rheostat. A potentiometer, graduated in T.U.'s, is fitted on this bay to control the input level from line.

Test Amplifier.—The calibrated test amplifier is used in conjunction with a non-reactive artificial cable, to provide a testing circuit enabling transmission gains up to 34 T.U.'s or losses up to 27 T.U.'s to be obtained for testing the operation of the transmitting and receiving circuits.

The gain characteristic of the test amplifier over the frequency range is flat.

The test amplifier can also be used as an end repeater and in the case of a breakdown, if an aerial line is used as a substitute, the installation can be made to function within the limits specified above.

Valve Voltmeter.—The valve voltmeter used is a Tinsley Portable Reflecting Galvanometer 0-5 microamps (resistance approximately 700 ohms), fitted with an 18 v. Osram lamp, and is used in conjunction with two V.T. 25 valves. By means of a key the secondary of the input transformer can be so arranged that the scale can be varied to read 0-1, 0-2 and 0-10 volts.

Telegraph Test Set.—The telegraph test set consists of two keys and a galvanometer and is provided to enable simple tests to be made on the local telegraph lines, between the voice frequency office and the telegraph instrument room. One key provides for sending a marking or spacing current to line *via* the galvanometer. The other key, in one position puts a loop or earth on the line and in the second position sends a current to line through the test galvanometer.

Transmission of a Signal.—This may be followed from Fig. **7** which shows a schematic diagram of the system.

The transmitting frequency is maintained throughout by a valve maintained tuning fork and a definite portion of the output is tapped off by means of the potentiometer (0-350 ohms), the circuit being closed through the primary of the input transformer and the tongue and marking stop of the telegraph relay. A signal from the telegraph office passes through the adjustable resistance (0-250 ohms), galvanometer, line coils of the telegraph relay to earth or back on the " B " line.

When the telegraph relay is operated, the tongue is moved over to the marking contact and so closes the output circuit. The secondary of the input transformer, which is in series with the secondaries of the input transformers associated with the other transmitting units, is connected to the grid of the common transmitting amplifying valve. The anode of this valve is coupled *via* an output transformer to a non-reactive adjustable artificial cable (0-10 T.U.'s), which is connected to the primary of a line transformer. Signals received on the grid of the common transmitting amplifier are amplified and passed to line *via* the adjustable non-reactive artificial cable. It is therefore possible to control the power level at the sending end.

At the receiving end of the line the incoming oscillations are passed to the grid of the common receiving amplifying valve *via* a line transformer, potentiometer calibrated in T.U.'s

(0-10), and an input transformer. From the anode of this valve the amplified oscillations are passed to their respective band filter *via* the secondary of an output transformer in the anode circuit. The six filters are connected in parallel. Across the output end of each filter there is a potentiometer so designed that for each step, one eighth of the filter output can be passed to the receiving unit. After passing through the relative filter the oscillations reach the grid of the amplifying valve of the particular receiving unit *via* an input transformer. This valve is transformer-coupled to a rectifying valve, in the anode of which is the primary of a transformer, the secondary being closed by a telegraph relay. A bye-pass condenser is connected across the primary of the transformer in order to pass the A.C. component of the rectified current. Rise of current in the primary of the transformer generates an impulse in the secondary, and the relay, which is normally set neutral, is actuated. Decrease of current in the primary generates an impulse in the secondary in the reverse direction, and the relay is operated accordingly. The relay is so arranged in the circuit that the impulse generated during the rise of current operates it in the " marking " direction. It follows therefore that the impulse generated during a decrease of current will operate the relay in a " spacing " direction. Signals are passed to the telegraph office from a local battery *via* the relay tongue, galvanometer and an adjustable rheostat. The positive and negative voltages for the relay contacts are supplied from an earthed battery.

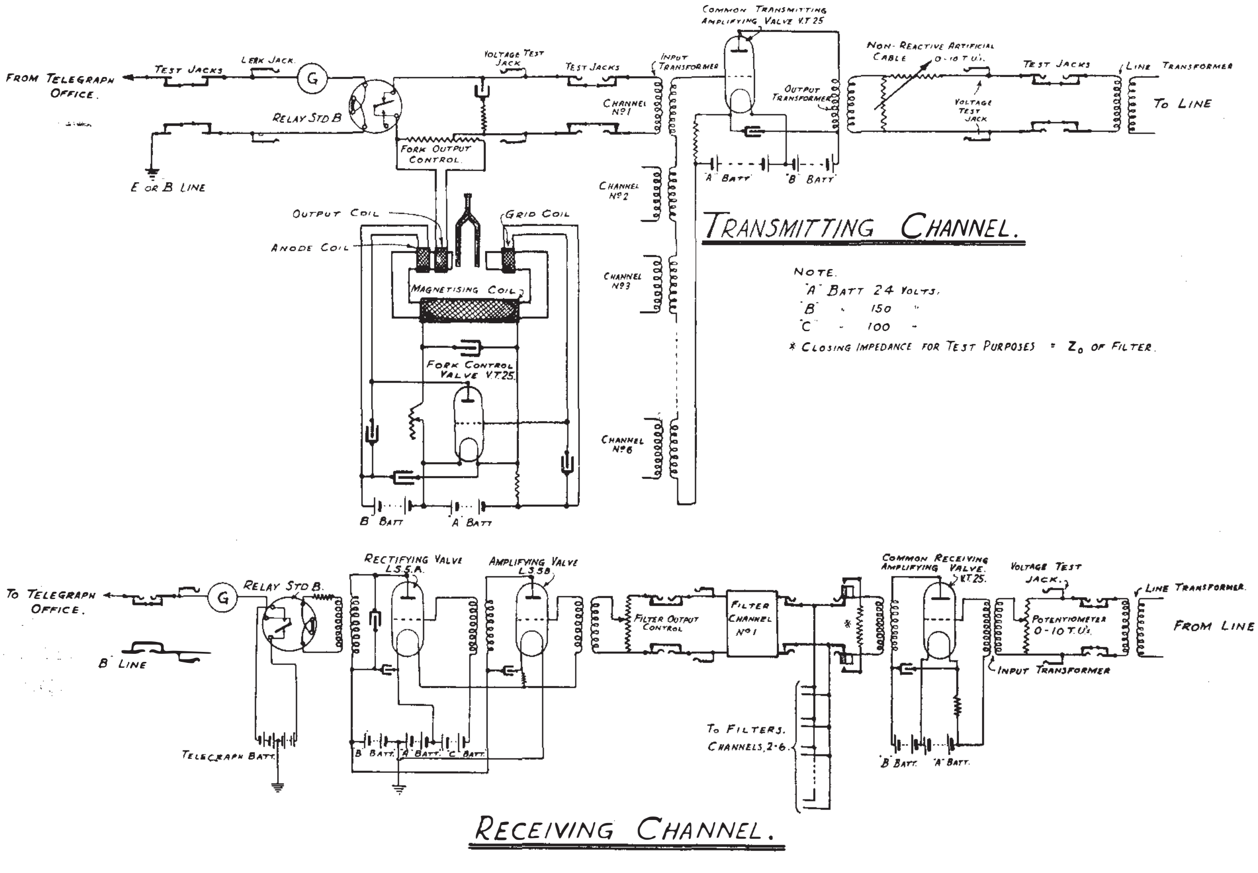

FIG. 7.—SCHEMATIC DIAGRAM OF SYSTEM.

Speed Trials.—Two complete sets forming the necessary equipment for two ends were made by the General Electric Company and, after satisfactory acceptance tests had been carried out, were installed in the Repeater Room Trunk Exchange, London, and the Telephone Repeater Station, Leeds.

A four-wire circuit was provided with repeaters at London, Fenny Stratford, Derby and Leeds, details of which are given in Tables 1 and 2.

TABLE NO. 1.

CIRCUIT DETAILS.

Pairs.		Cable.	Type and Loading.	Miles.
Go	Return.			
103	104	London-Derby.	20lbs. Side Circuits loaded with 78 mH. coils. 2000 yds. spacing.	127.474
45	46	Derby-Leeds.		69.538

TABLE NO. 2.

REPEATER SETTINGS.

	Trunk Exchange London.			Fenny Stratford.			Derby.			Leeds.		
Circuit.	Potentio-meter	Equaliser	Gain S.M.	Potentio-meter	Equaliser	Gain S.M.	Potentio-meter	Equaliser	Gain S.M.	Potentio-meter	Equaliser	Gain S.M.
Go	6/5⅓	$A_1B_1C_5$	9	8/5	$A_1B_1C_5$	17.2	11/5⅔	$A_1B_1C_5$	32.3	8/4⅔	$A_1B_1C_5$	18.3
Return.	6/4	$A_2B_3C_{12}$	9	9/9⅔	$A_1B_1C_5$	31.5	9/7	$A_1B_1C_5$	26.2	6/6	$A_2B_2C_{11}$	9.

With the circuit so lined up, a zero loop was provided for transmission between London and Leeds and a small loss between Leeds and London.

As the phantom of this circuit was already in use, a temporary two-wire circuit was allocated as a telephone speaker during the trials.

The output of the Voice Frequency sets at London and Leeds was adjusted to 0.2 volts per channel. The several adjustments under these conditions to give a rectified current of approximately 10 m-Amps are shown in Tables 3 and 4.

TABLE NO. 3.

VOICE FREQUENCY SETTINGS AT LONDON.

Channel.	Tuning Fork Output Volts.	Volts sent to Home Repeater.	Filter Output Volts.	Filter Output Potentiometer Setting.	Rectified Current Milliamps.
1	0.31	0.2	0.35	5	10
2	0.27	0.2	0.35	6	11
3	0.28	0.2	0.35	5	10.5
4	0.28	0.2	0.32	5	11
5	0.28	0.2	0.34	5	11
6	0.29	0.2	0.32	6	10

Total Volts sent to Home Repeater = 0.48 Volts.
Total Volts received from Home Repeater = 0.32 volts.
Output from receiving master amplifier = 1.56 volts.

TABLE NO. 4.

VOICE FREQUENCY SETTINGS AT LEEDS.

Channel.	Tuning Fork Output Volts.	Volts sent to Home Repeater.	Filter Output Volts.	Filter Output Potentiometer Setting.	Rectified Current Milliamps.
1	0.28	0.2	0.68	5	10.5
2	0.28	0.2	0.52	5	10
3	0.29	0.2	0.61	5	10
4	0.27	0.2	0.60	5	11
5	0.26	0.2	0.59	5	11
6	0.27	0.2	0.53	5	10.5

Total volts sent to Home Repeater = 0.475 volts.
Total volts received from Home Repeater = 0.48 volts.
Output from Receiving Master Amplifier = 2.4 volts.

Settings Common to both ends.

All Filament Currents 0.83 amps.

Fork Magnet Polarising Current 25 milliamps.

Attenuating Network at Sender Output 2 T.U.'s.

Receiving Potentiometer 2 T.U.'s.

Wheatstone trials were first carried out at both ends, using P.O. type Wheatstone Transmitters and Receivers, a shunted condenser of 2μF. and 2000 ohms being connected in series with the coils of each receiver.

Slip was run continuously on each channel for one hour, with all other transmitters running reversals and occasional slip. Good signals were received on each channel at 100 w.p.m.

Trials were next carried out, using Creed Perforators and Printers under the same conditions as before. On each channel "Creed" working was obtained at 100 w.p.m.

The set made by the General Electric Co. and described in this article is the first of its kind to be installed and, with the exception of the Siemens Halske system, which is working between London and Manchester, is the only system of voice frequency multiplex telegraphy at present used in this country.

The possibilities of voice frequency telegraphy are varied, and its applications are numerous, but it is considered that these questions do not come within the scope of the present article. It may be mentioned, however, that it is possible to work a single channel system (on 20 lb. loaded underground conductors) at 300 words per minute, and at the other end of the scale, by closing up the filter bands, a twelve channel system giving about 60-70 words per minute per channel could be used. The first should prove useful where high speed working is required on small gauge underground conductors, whilst the second is essentially suited for start-stop telegraph systems.

In conclusion, the authors would like to thank Colonel T. F. Purves and Mr. S. A. Pollock for permission to use certain information contained in this article, and they are also indebted to Sir W. Noble and Capt. Hannam-Clark, of the General Electric Co., for the loan of photographs and diagrams.

CARRIER CURRENT TELEPHONY.

A. C. Timmis, B.Sc., A.M.I.E.E.

I.—Historical.

UNDER the inaccurate but expressive name of "wired wireless" the system of telephony or telegraphy now described as carrier current working was generally known, though not used commercially, for some years before the war. Immediately after the war rapid developments took place in America, Germany and this country, for very different reasons.

In the U.S.A. there are many long telephone lines on which the value of an extra channel of communcation is sufficient to justify the use of very expensive terminal equipment.

In Germany, for some time after the end of the war there was a serious shortage of copper and an urgent demand for new circuits which could be met only by using the carrier current system on existing aerial lines. The extensive system of underground cables and repeater stations which now covers Germany has replaced practically all these carrier circuits. They were only economical as a means of tiding over a special difficulty.

In this country also it is, in general, more economical to provide the longest circuits by means of cables and repeater stations than by superposing carrier channels on the aerial lines. There are, however, special cases where the traffic does not justify laying a cable or where for some reason the cost of a physical circuit is unusually high. For instance, the cost of a submarine cable between England and the Continent is sufficient to justify very expensive terminal apparatus in order to provide additional circuits by means of carrier working. At the present moment there are 10 carrier telephone circuits working on aerial lines in Great Britain. They vary in length from 60 to 200 miles.

Recently a special low frequency carrier system has been developed for use on continuously loaded paper core submarine cables of the type in use between England and the Continent, and schemes are now in hand for working carrier circuits on other submarine cables. A special type of cable has been designed for multi-channel carrier working over considerable distances.

In France and elsewhere on the Continent carrier working on aerial lines has been introduced with success by the International Standard Electric Corporation (using American sources of inspiration). A carrier circuit has the great advantage that it is comparatively unaffected by induction from power lines. This induction is becoming a serious difficulty on long aerial lines on account of the rapid growth of high voltage power distribution systems, especially on the Continent.

In Germany and America carrier current telephony is being increasingly used for communication over power lines, the telephone system being coupled to the high-voltage wires by means of special condensers, or a wire run for a few spans underneath the power wires.

In America progress has been very rapid.

About 200,000 channel-miles of carrier telephone circuits are working on aerial lines, and in many cases three channels of carrier are worked on one physical circuit in addition to sub-audio telegraphs, etc. A six-channel carrier telephone system is working on a single core submarine cable across the Catalina Channel.[*] This constitutes the highest development of carrier current telephony, as far as the writer is aware, and has been made possible by the American Telegraph and Telephone Co.'s patented system of " single side band " working.

As regards carrier telegraphy, although it is technically a simpler matter than carrier telephony, no circuits have been tried as no demand has arisen in this country. It has recently been proposed, however, to use carrier telegraphy on several of the cross-channel cables. In America a large number of carrier telegraph circuits are in use.

II.—GENERAL PRINCIPLES.

In a paper read before the I.P.O.E.E. by Taylor and Bradfield[†] the general principles of carrier current telephony were briefly explained. It is necessary, therefore, only to generalise and extend the information there given as regards recent developments in the art.

The essential difference between carrier current telephony and wireless telephony or broadcasting is in the medium used for transmission. In both cases a carrier current is modulated (*i.e.*, made to vary in amplitude in accordance with speech) at the transmitting end and demodulated or " detected " at the receiving end.

In the case of line transmission, however, the carrier frequency is generally much lower and the well known laws of transmission at audio frequencies apply strictly. The so-called constants of the line must of course be known for the frequency in question. Inductance and capacity do not change appreciably, but in the case of open lines and cable circuits the resistance and leakance increase rapidly in the ordinary carrier frequency range of 7 to 30 kilocycles. Cross-talk, or over-hearing, becomes much more serious than at audio frequencies. In some cases this effect is so pronounced that at certain frequencies the attenuation of a circuit may be doubled or trebled by the absorption of energy through cross-talk to another circuit.

The attenuation of cable circuits at carrier frequencies is much higher than that of aerial circuits, and coil-loaded cables of the type generally used for telephony are out of the question for carrier working.

By using carriers of different frequencies several channels of communication may be superposed on the same physical circuit, and prevented from interfering with each other by the use of filters. Unfortunately, owing to the lower frequencies which must be used, this separation cannot be accomplished by means of simple tuned circuits such as those used in wireless telephony. To explain this, it is necessary to consider in some detail what is involved in a modulated carrier current.

If we send to line a steady A.C. at a frequency of, say, 10 kilocycles and demodulate or " detect " it in the ordinary way, nothing will be heard in the receiver. But if the amplitude of the 10 kilocycle carrier be varied sinusoidally at a frequency of, say, 1000 cycles, a note of this frequency will be heard in the receiver. At first sight it would appear that the line current is simply an A.C., having a constant frequency of 10 kilocycles but a varying amplitude; so that the receiver could be tuned very sharply to 10 kilocycles and be unaffected by another carrier frequency of, say, 10.5 kilocycles. This is a fallacy, as can be shown very simply: Let $A \sin \theta t$ represent the unmodulated carrier whose amplitude is to be varied in accordance with an audio frequency, $\sin \phi t$, between the limits $A(1+k)$ and $A(1-k)$, k being less than 1.

The modulated wave will be:

$$A \sin \theta t\,(1 + k \sin \phi t)$$
$$= A \sin \theta t + Ak \sin \theta \sin \phi t$$
$$= A \sin \theta t - \frac{Ak}{2} \cos(\theta+\phi)t + \frac{Ak}{2} \cos(\theta-\phi)t$$

= carrier + upper side band + lower side band
(carrier + audio) (carrier − audio)

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[*] *" Carrier Current Communication on Submarine Cables," by H. W. Hitchcock. Bell Telephone Laboratories. Reprinted B.222, Nov., 1926.*

[†] *" Some Experiments on Carrier Current Telephony," by C. A. Taylor and R. Bradfield. I.P.O.E.E. Paper No. 86.*

That is, reverting to the numerical example above, the line carries a frequency of 10 kilocycles and in addition frequencies of 9 kilocycles and 11 kilocycles:—the lower and upper side bands respectively.

Therefore the tuning of the receiver must be broad enough to cover the range from 9 to 11 kilocycles, which is twice the audio frequency. It is beyond the scope of this article to attempt a complete mental picture of what happens when a carrier wave is modulated, but it is essential to realise that amplitude cannot be changed at any finite rate without entailing a change of frequency, and *vice versa.* This change of frequency and amplitude is exactly equivalent, electrically, to the addition of the side bands.

If we take the highest audio frequency required to be transmitted as 2500 cycles, the essential frequencies to be transmitted will occupy a range of 5000 cycles, and the difference between two carrier frequencies to be transmitted on the same line must be somewhat greater than 5000 cycles. It will be evident that the necessary selectivity cannot be obtained so simply as in the case of wireless broadcasting. In practice, band filters are always used to separate the different carriers, and the number of such carriers is very limited.

There are, broadly, two methods of superposing carrier circuits (or channels) on a physical circuit, which may be called the " balanced " and the " grouped " system, respectively. In either case, filters must be provided to separate the audio from the carrier channels, and the latter must be arranged for two-way working in order to be used as commercial telephone circuits.

When the balanced system is used, the same carrier frequency is employed for transmitting in each direction and interaction between the transmitter and receiver at each end of the line is prevented by a differential transformer and line balance, exactly as in the case of audio two-way repeaters.

In the grouped system different frequencies are used in the two directions, and interaction between transmitter and receiver is prevented by filters.

The balanced system has the advantage that it only uses one frequency per channel, and more channels can therefore be worked within the ordinary range of, say, 7 to 30 kilocycles. On the other hand very accurate balancing, or simulation of the line impedance, is necessary and the system is only practicable on comparatively short and uniform lines. The grouped system can be applied to longer lines and uniformity is not so important. But, other things being equal, only half as many channels can be superposed on one physical circuit, as compared with the balanced system. Further, a carrier circuit using the same or different frequencies for the two directions may be divided between two physical circuits, one being used as a " go " and the other as a " return." This is the equivalent of a four-wire telephone circuit.

The application of either system of carrier working is facilitated by the use of single side-band working. This system, originated by J. R. Carson, of the American Telegraph and Telephone Co., is an inspiring example of the direct application of high mathematical analysis to the solution of an engineering problem. Stated very briefly the system is as follows:—Modulation of the carrier is effected in such a way that the two side bands (see above) are produced without the carrier frequency. One side band is then filtered out, and only the other side band transmitted over the line. At the receiving end this side band is added to a locally generated carrier, of the right frequency of course, and made to reproduce the original speech or other modulating frequency. By this means the width of the frequency band required for each channel is approximately halved, and certain difficulties which arise when carrier and side bands are transmitted in the usual way disappear. It is not proposed to deal with this system in detail, however, as the main purpose of the present article is to describe some of the research work recently undertaken by the British Post Office in connection with ordinary carrier working.

III.—Transmission.

The characteristics of aerial lines, paper-core cables, and G.P. cables at carrier frequencies have been measured in this country and in America. A paper read before the A.I.E.E. in 1921 by Colpitts and Blackwell* contains much valuable information, which is confirmed and extended in an article by Affel, Demarest and Green in the Bell Technical Journal, July, 1928. Measurements recently made here agree fairly well with the American results, allowance being made for the different type of line construction. Fig. 1 gives the attenuation-frequency characteristic of an aerial line (twist system throughout) between Taplow and Plymouth, a distance of 200 miles. The measurement was made on a fine summer night. The same line was also measured when the conditions of humidity were extraordinary, even for our much-abused climate, and the attenuation was almost doubled. Such an effect is fortunately rare. The conditions were so bad, in fact, that the ordinary aerial trunks were noticeably affected. For aerial lines of such a length that carrier working is economical it is generally impracticable to use frequencies much above 30 kilocycles. This limit does not necessarily apply to cables, however, where the cross-talk may be very much less, though the attenuation is generally much higher.

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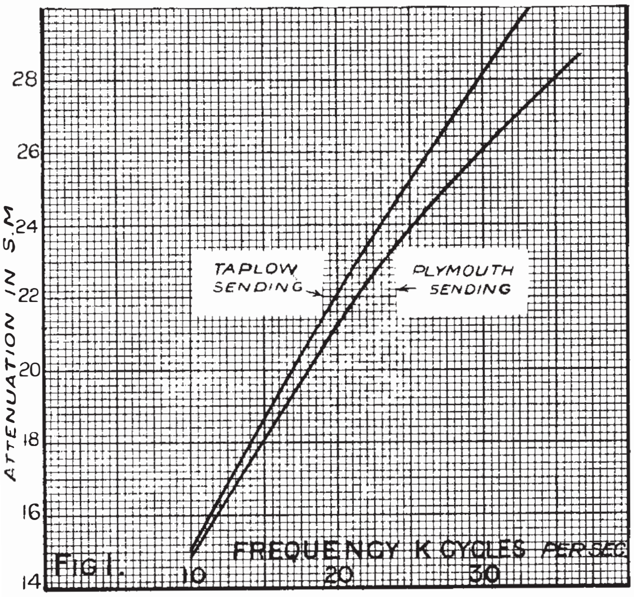
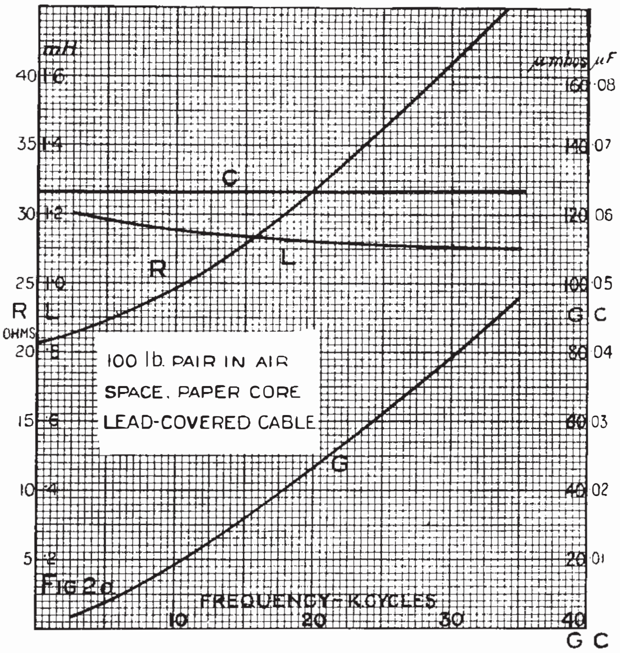
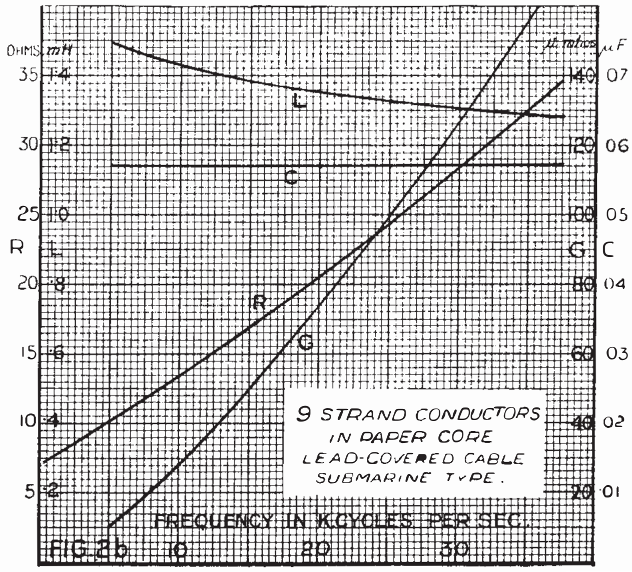
* " *Carrier Current Telegraphy and Telephony.*"



The factors governing the attenuation of cable pairs will be dealt with in some detail, as they have been fully investigated with a view to designing submarine cables on which carrier working may be possible over considerable distances.



The four constants, R, L, G and C, were determined from impedance measurements on short lengths of cable (30 to 180 yards) with the far end of the tested pair open and closed. Two measurements at each frequency were therefore required. As the lengths were extremely short, electrically, the closed impedance could be taken as $(R + j\omega L) \times$ length and the " open " impedance as $\frac{G + jC\omega}{\text{length}}$. A proof of this will be found in J. G. Hill's " Telephonic Transmission," p. 246. The measurements were made by a substitution method, using a bridge of very high quality, with a heterodyne detector unit in



place of the usual telephone receiver. This was adjusted to give a balancing note of about 1000 cycles. It was found essential to use the Wagner earthing device, which enabled the detector to be brought to Earth potential at each balance of the bridge, but no specially elaborate screening arrangements were used. The resistance, which proved to be the most important factor determining attenuation at high frequencies, was generally a matter of two or three tenths of an ohm, and great care was necessary to measure it accurately.

Similar measurements were made in 1922 by Messrs. Taylor and Bradfield, using only 10 ft. of submarine cable. Their method was different in detail but the results agree very well with the recent measurements now being described. Curves showing R, L, G and C for some typical cases are given in Fig. **2** (*a*, *b*, and *c*). These results have been verified by direct measurement of the attenuation of various cables *in situ*.

Two important facts emerge from these measurements:—(1) At frequencies over 6 or 7 kilocycles the characteristic impedance of any cable pair becomes approximately non-reactive. The same thing also applies to aerial lines. (2) The rise of effective resistance with frequency is very rapid, on account of the skin effect in solid conductors and eddy current losses in the sheath or (in the case of submarine cables) the armouring and surrounding sea water. The rise of resistance with frequency is shown by the curves for R in Fig. **2**.

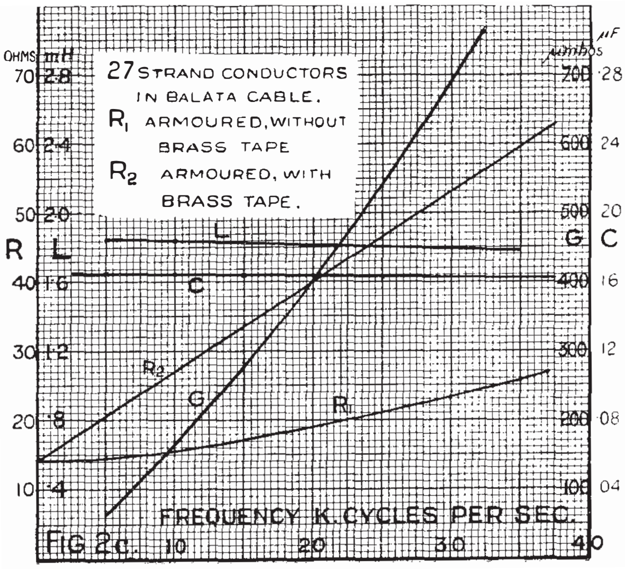


FIG 2c. 27 STRAND CONDUCTORS IN BALATA CABLE. R_1 ARMOURED, WITHOUT BRASS TAPE R_2 ARMOURED, WITH BRASS TAPE.

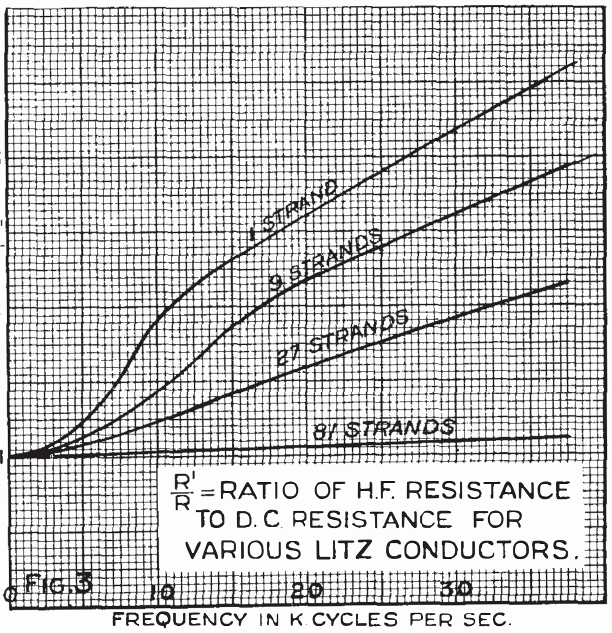


FIG. 3. $\frac{R'}{R}$ = RATIO OF H.F. RESISTANCE TO D.C. RESISTANCE FOR VARIOUS LITZ CONDUCTORS.

It is evident that the attenuation of cables at high frequencies can only be reduced to manageable values by reducing effective resistance. The skin effect can be almost wiped out by making the conductor of 3^n strands, in what is known as " Litz " formation. Three wires are first stranded together. This group of three is stranded with two similar groups, and so on. (Obviously the number of strands must be a power of 3). The effect is that each strand occupies in turn all possible positions from centre to outside. It was thought that the increase of resistance in a Litz conductor would be merely that corresponding to one strand. But it was found, at any rate for carrier frequencies, that this is only true for conductors of 81 strands or more.

The next lower number possible (27) is very nearly as efficient and not impracticable from the point of view of size and jointing.

Fig. **3** shows the relative efficiency of 1, 9, 27 and 81 strands. $\frac{R^1}{R}$ is the ratio of total resistance to D.C. resistance, and the total weight of the conductor is 350 lbs. per mile in each case. For the same weight a Litz conductor has the disadvantage of greater diameter than a solid conductor, or one stranded with parallel wires as is usual in submarine cables for mechanical reasons. The greater diameter means increased capacity and eddy current losses in the sheath. To decide whether the advantages of Litz conductors would outweigh their disadvantages, two lengths of paper-core lead-covered cable were made up. One contained four conductors in star quad formation, each having 27 strands of No. 26 S.W.G. The other was similar as regards formation, thickness of paper, etc., but contained solid conductors of the same weight—160 lbs. per naut. Fig. **4** shows R and β for both these cables, and the advantage of the stranding is evident at high frequencies.

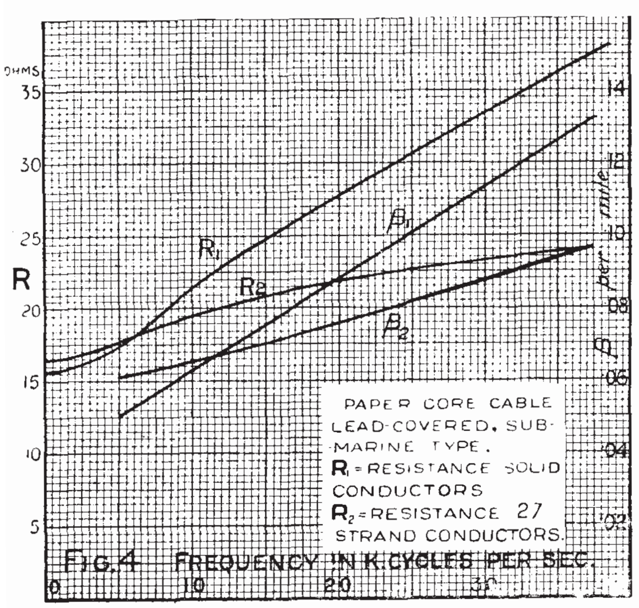


FIG. 4

The laws governing these eddy current losses are still very obscure, but certain facts are clear; *e.g.*, the closer the conductors and the greater the diameter of the sheath the less the eddy current loss. In the case of G.P. submarine cables the Litz conductor is essential for reasonable high-frequency attenuation, but the type of sheathing also has a very important effect. For instance, the brass tape usually wound over the core to prevent damage by the teredo worm is responsible for most of the resistance rise.

In co-operation with Messrs. Siemens Bros., many different types of armouring have been tried. The most surprising of all the results was that a cable covered with steel armouring wires and no brass tape gave a lower attenuation than the same cable unarmoured; both being tested immersed in salt water.

Fig. **5** shows the attenuation, calculated from measurements of R, L, G and C on a short length of a Balata cable, 4—27/26 conductors, armoured, no brass tape.

The matter cannot be discussed in more detail at this stage, but the position may be summarised thus:—

(1) For lead-covered cables (land or submarine) conductors formed of 27 strands in Litz formation and stranded into a star quad, with suitable thickness of paper insulation, will give reasonable attenuation at carrier frequencies up to 30 kilocycles or more.

(2) In cases where G.P. cables must be used, similar conductors, armoured but not covered with brass or other metallic tape, are indicated. Balata would generally be used, except at the shore ends, instead of G.P., as the dieletcric losses are much lower at audio and somewhat lower at carrier frequencies. The risk of damage by teredos varies greatly in different waters. To meet cases where this risk is considerable, various forms of protection which will not increase the eddy current loss are being considered.

Continuously loaded cables.—The attenuation of continuously loaded cables increases rapidly as the frequency is increased from about three kilocycles, mainly owing to eddy current losses in the loading material. A typical attenuation-frequency curve (taken from the Anglo-Dutch No. 3 cable) is shown in Fig. **6.** It was evident from measurements of this kind, together with cross-talk measurements made at carrier frequencies with a special amplifier, that only a

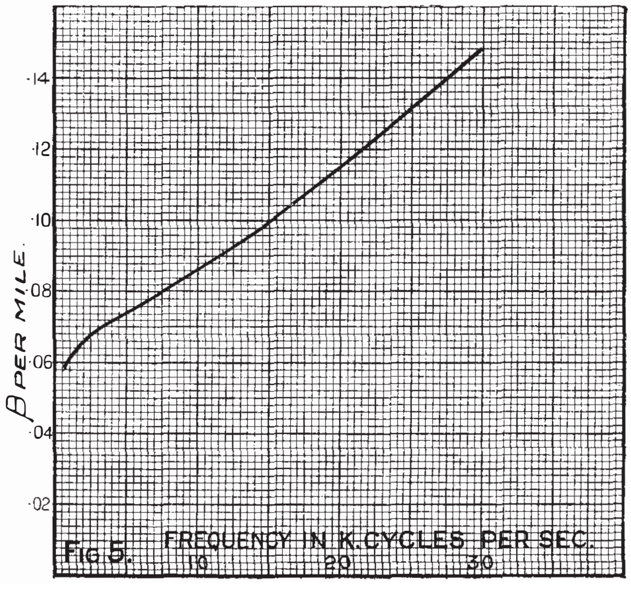


Fig 5.

relatively low carrier frequency could be used on the continuously loaded cables between England and the Continent. Taking 2500 as the highest frequency for good speech, and a carrier frequency of 6000, the lower side-band extends down to 3500, leaving a margin of 1000 cycles between the audio and carrier channels. It has been found quite practicable to work with a 6000 cycle carrier, and the system is now emerging from the experimental stage. The arrangement of the apparatus will be described in the next section.

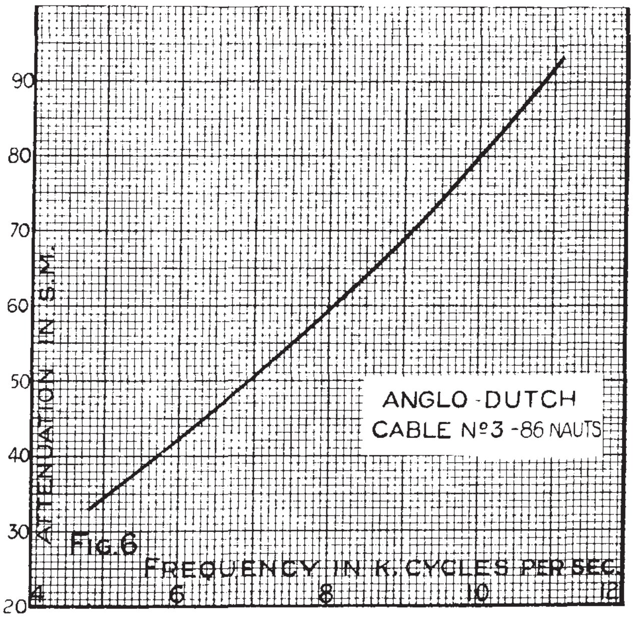


Fig. 6

IV.—Apparatus.

The apparatus at present in use for carrier telephone circuits on aerial lines in this country is a somewhat improved version of that described in Taylor and Bradfield's paper, referred to in Section II. This apparatus is giving satisfactory service for single channel working, but the design of improved sets, using high-frequency filters and adaptable for two-channel working, is now in hand. For carrier working on continuously loaded cables at a frequency of 6000, special arrangements are necessary to obtain a satisfactory separation of the audio and carrier channels. High-pass and low-pass filters are used at both ends. At the transmitting end a special form of modulating circuit is used to separate the audio from the carrier frequency. In view of the high line attenuation to be dealt with (over 40 S.M.) there is perforce an unusually great difference of level between the carrier and the physical circuit, and it would be a difficult matter to provide the necessary separation by means of filters alone. Special precautions have to be taken to prevent audio to carrier cross-talk through the repeater station common batteries supplying filament and anode current to the sets. The general arrangement is given in Fig. **7**, which shows the apparatus for one carrier circuit superposed on one quad of the cable. Three physical circuits are working; two sides and one phantom, with two-wire repeaters. The carrier is worked as a four-wire circuit, the " go " on one side circuit and the " return " on the other. One end of the cable only is shown. The other is exactly similar, except that modulator and demodulator are interchanged. The audio extensions of the carrier may be connected to a four-wire circuit on the land side, or combined by means of the usual differential transformer to form a two-wire circuit. Considering the physical circuits first: These have been shown as two-wire repeater circuits because most submarine cable circuits are worked in this way. In the case of four-wire circuits the problem is simplified by the absence of balances. An impedance adjusting network (Z in the figure) is inserted in each cable pair to make the impedance approximately non-reactive. The HP and LP filters are so designed that the whole arrangement viewed from the line side of the terminal transformer has an impedance which is very nearly non-reactive over the audio frequency range. The repeater on each side circuit is therefore balanced (on the cable side) by a simple resistance connected through a transformer corresponding to the terminal transformer. The phantom circuit repeater is balanced by a network containing inductance. If signalling is by means of voice frequency currents, there are no difficulties, but

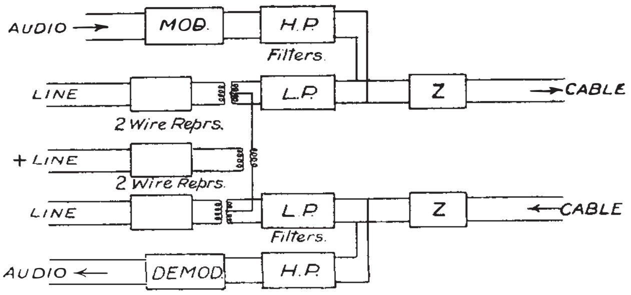


Fig. **7**.

in some cases 16-cycle or 25-cycle ringing is still used. Certain modifications have then to be made in the impedance adjusting networks to allow the low frequency currents to pass. Signalling over the carrier circuit must be done by voice frequency currents.

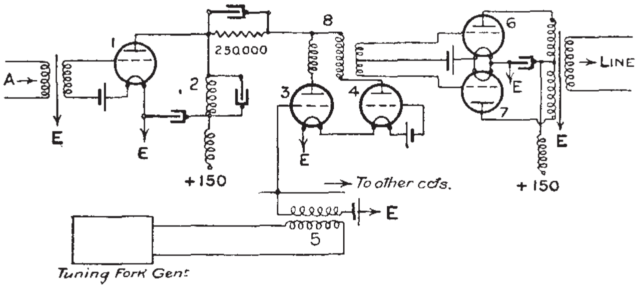


FIG. 8.

The carrier current is generated at each end of the cable by a 6000 cycle valve-maintained tuning-fork, which supplies all the carrier channels. It is found that the carrier frequencies at the two ends must not differ by more than 2 or 3 cycles per sec., but no difficulty is anticipated in this respect in view of the exteme constancy of which tuning-fork generators have been proved capable.

The arrangement of the modulator is shewn in Fig. 8. Speech entering at A is amplified by the valve 1 and varies the voltage across modulating choke 2. This variation of voltage controls the carrier output of valve 3 (to the grid of which carrier frequency is supplied through the transformer 5) in accordance with the speech. Valve 4 is arranged to act, through the transformer 8, to balance the audio-frequency effect by which the speech currents tend to pass straight through the modulator, with amplification, and so to line. The valves 6 and 7 act simply as a push-pull amplifier of the modulated carrier, which then passes through the H.P. filter to line. The discrimination between audio and carrier frequencies afforded by the balancing valve (4) and the H.P. filter is such that cross-talk from the carrier to the physical circuit is better than 80 S.M. The normal carrier current sent to line is about 15 milliamps, and the modulation factor 50% for ordinary speech. The main object in using a push-pull amplifier is to improve the balance to earth of the output transformer. If a balanced and screened output transformer is used with one half of the primary left disconnected at the outer end, a single valve, or two valves in parallel, may be used for the amplifier with satisfactory results.

The modulating choke is shunted by a condenser and the combination forms a parallel resonant circuit having a high impedance over the audio frequency range. The 250,000 ohm resistance cuts down the effective anode voltage of valve 3 to a suitable value for modulating. Carrier frequency is supplied through the balanced-and-screened transformer 5 to the grids of the transmitting valves on each carrier circuit, all the grids being in parallel. Interference is avoided by adjusting the grid bias so that grid current never flows, and by the use of " neutrodyning " condensers where necessary.

The demodulator, or carrier receiver (Fig. 9) consists of an amplifier valve (1), followed by a rectifying valve (2), which is primed to act as a bottom-bend rectifier. The output from transformer 3 consists of audio frequency with a 6,000 cycle ripple. This is practically eliminated by the line, or the normal filters used in two-wire repeaters, in most cases. Otherwise, a L.P. filter is connected in the output circuit.

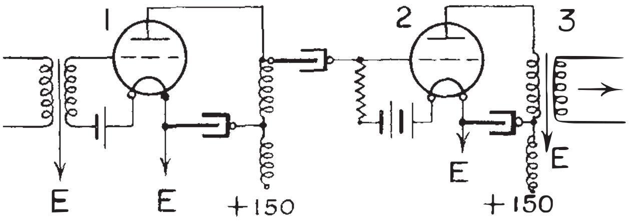


FIG. 9.

The efficiency of the rectifying circuit can be improved by using two rectifiers joined in the well-known manner to give full wave rectification, and in this case the ripple has a frequency of 12,000 cycles, which facilitates filtering. Incidentally, a Westinghouse metal rectifier, consisting of four elements arranged in bridge fashion for full wave rectification, was found to give satisfactory results. In this case also the frequency of the ripple was 12,000 cycles, in consequence of the full wave rectification.

No details of battery supply to the filaments have been shewn in the diagrams, since the exact arrangement depends on the batteries available, but in practice the ordinary repeater station batteries are used for heating and anode supply.

Where the grids cannot be primed from resistances in the filament circuit primary cells are used.

In applying this carrier system to such cables as the Anglo-Dutch and Anglo-Belgian, where the carrier attenuation is about 40 S.M., there are four main difficulties to be overcome:—

(1) Battery cross-talk between one carrier current and another, and between carrier and audio.

(2) Cross-talk from carrier to audio due to the non-linear magnetic characteristics of the loading material, which tends to rectify the carrier currents and make them audible on the physical circuit.

(3) Cross-talk from audio to carrier, due to modulation of the carrier current by speech currents, the latter varying the permeability of the loading material and hence the attenuation of the carrier current, so modulating it in accordance with the speech on the physical circuit.

(4) Carrier to carrier cross-talk between different quads of the cable.

Of these difficulties the first was overcome by special smoothing arrangements in filament and anode circuits. The second and third fortunately proved of insufficient magnitude to cause much trouble. The last has proved the most serious, since it is governed almost entirely by the construction of the cable, and very little can be done to improve matters after the cable is laid. A trial under working conditions is the only safe method of deciding on which of the quads in a large cable the system can be worked satisfactorily.

The same type of apparatus will shortly be applied to single and double channel carrier working on aerial lines and possibly unloaded cables, where higher carrier frequencies can be used; but at present all the indications point to submarine cables, of the unloaded or continuously loaded type, as the most promising field of development.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

TELEPHONES AND WIRE MILEAGES, THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 30TH SEPT., 1928.

No. of Telephones owned and maintained by the Post Office.	Overhead Wire Mileages.				Engineering District	Underground Wire Mileages.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
598,538	517	4,043	51,575	130	London	24,522	68,949	2,315,957	99,413
77,349	2,158	21,416	65,578	1,854	S. East	4,023	49,018	197,457	32,733
80,662	4,348	30,906	56,402	3,253	S. West	20,631	12,403	152,815	59,303
63,471	6,063	37,291	59,494	5,473	Eastern	23,380	38,125	114,523	70,585
96,677	8,608	44,988	58,941	3,819	N. Mid.	29,518	54,017	241,480	113,174
78,862	4,786	29,938	72,085	4,604	S. Mid.	12,104	23,364	188,791	88,454
58,124	4,343	29,868	52,341	3,146	S. Wales	6,360	26,189	119,572	71,931
103,366	8,060	26,421	49,736	4,213	N. Wales	13,564	41,286	274,658	61,333
157,826	1,492	16,465	43,270	2,459	S. Lancs.	13,637	79,224	473,518	48,360
92,800	6,234	30,595	46,565	3,270	N. East	11,714	46,188	232,479	72,670
64,085	4,029	24,300	37,744	2,186	N. West	8,303	33,623	165,187	31,722
47,235	2,514	16,204	25,440	2,556	Northern	4,700	15,013	109,327	50,682
21,391	4,568	8,453	13,921	543	Ireland N.	134	2,324	40,346	1,577
65,533	5,472	26,141	37,485	1,443	Scot. East	3,954	12,906	151,144	47,260
87,699	7,274	24,310	42,862	1,089	Scot. West	12,077	24,606	224,278	37,189
1,693,618	70,466	371,339	713,439	40,038	Total	188,621	527,235	5,001,532	886,386
1,668,098	70,768	370,327	707,061	38,951	Figures as at 30th June, 1928.	184,835	517,854	4,859,655	897,031

TELEPHONE REPEATERS AT NEW DELHI.

N. F. Frome.

Introduction.—The small cord circuit telephone repeater installation described in the following account is that of the repeaters in use in the New Delhi trunk exchange. The apparatus includes one or two novel circuit arrangements which are illustrated in the diagrams. Examples of typical line and network impedance curves are shown.

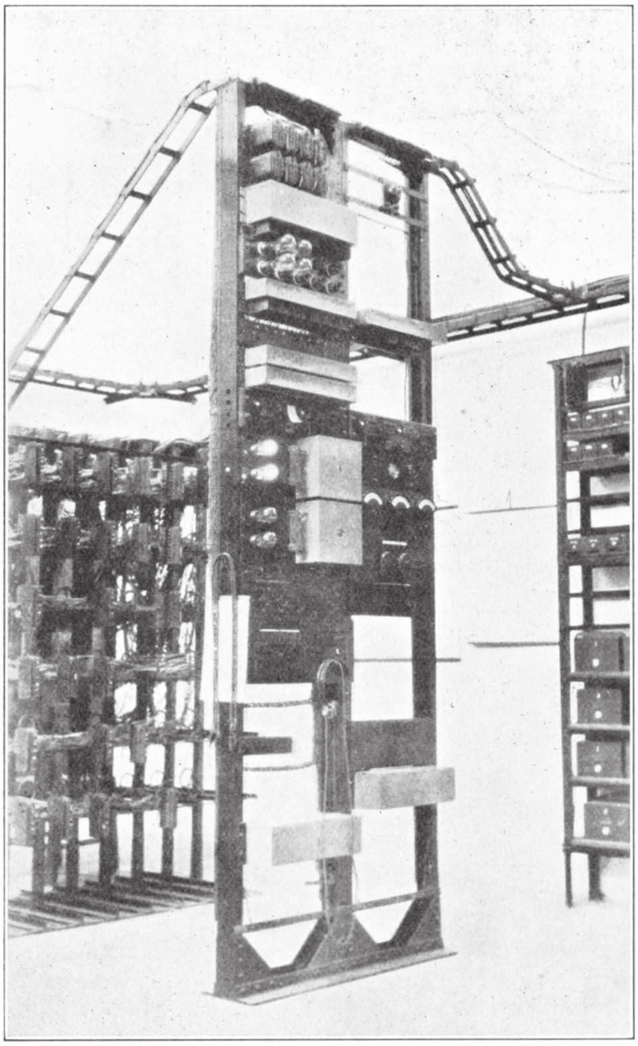


Fig. 1.—General view. Cord Circuit Repeaters.

Repeaters.—The repeaters are of the General Electric Company's type No. 12A (Fig. 1). They are installed in the test room (described in Vol. XX., Part 3, page 163), which is adjacent to the trunk exchange. One or two small modifications have been introduced on the repeater bay, viz.—

(1) The filament circuit is operated from the 40 volt trunk exchange battery instead of from the usual 24 volt battery.

(2) Lamps have been fitted in the potentiometer relay circuits to light in conjunction with the relays and indicate the step on which the repeater is being worked. The latter addition enables the test room staff to keep a constant watch on the repeater operation.

Cord Circuits.—Fig. 2 shows the repeater cord circuit which is designed to operate in conjunction with the cordless trunk switchboard. The latter is of a semi-automatic type in which connections are set up in relay selection circuits by the operation of selection keys and key-controlled link circuits. The repeater link switchboard fittings are exactly similar to those of the ordinary links with the addition of the potentiometer keys. "Control" keys are used for line selection and designation. "Ring," "Split," and "Speak" keys for ringing, temporarily terminating through calls, and speaking, respectively. A repeater call is set up as follows:—As a result of throwing the "Control" key CX, and pressing the selection key of a particular line, the line is connected to XT, XR, and XS; relay (9) is operated over the tens and units locking wires, relay (1) is energised and connects the line through to the X side of the repeater. The second line connection is similarly made using the CY key, relays (10) & (6) operate, completing the second line circuit to the Y side of the repeater. The filament start relay is energised *via* the contacts of (9) and (10), the lamp TSL indicating to the operator that the filament circuit has been completed.

The operation of the "Speak" key closes the circuit of relay (15) and connects the operator's telephone set to the monitoring winding of the repeater. To speak to one terminal station only, the "Split" key is thrown to SX or SY,

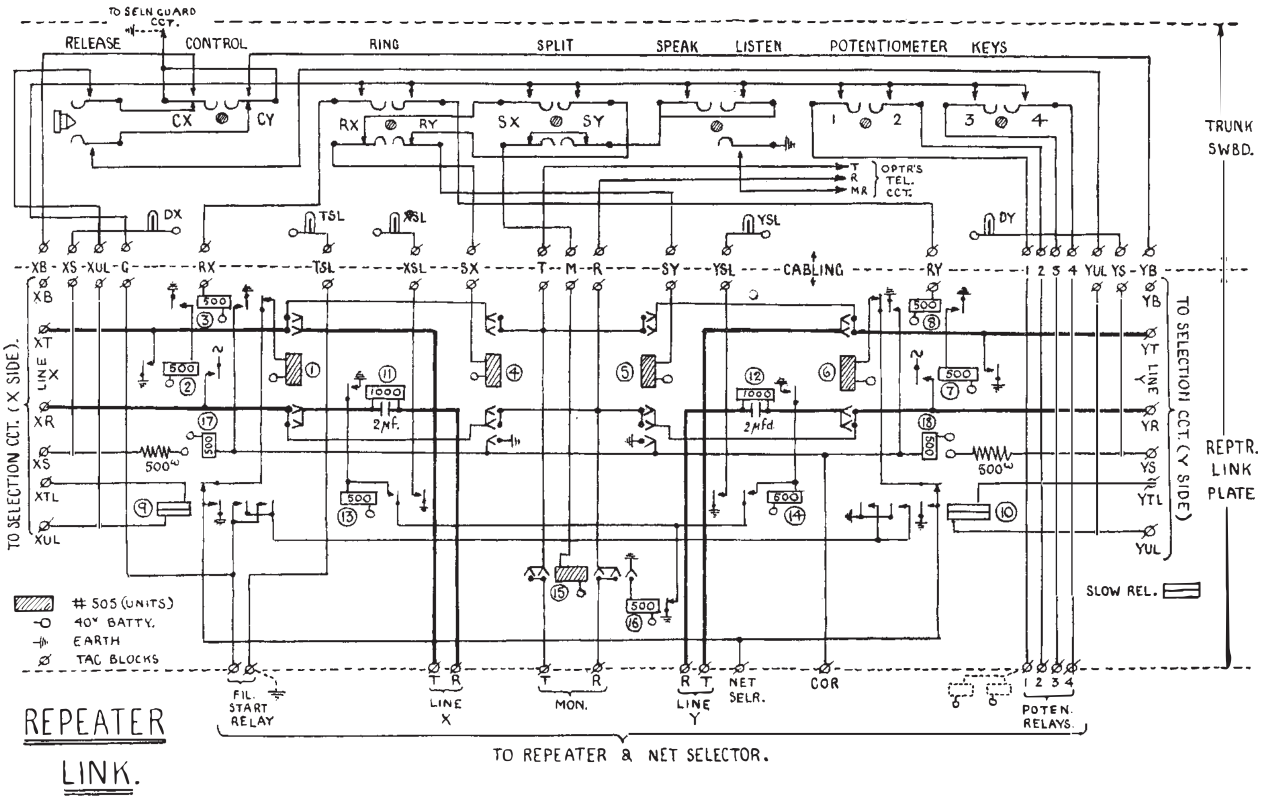


FIG. 2.—REPEATER CORD CIRCUIT.

operating relay (4) or (5) connecting the operator's telephone set to the one line. At the same time the repeater cut-off relay is energised, and the input transformers short-circuited, while relays (17) or (18) opens the circuit of (1) or (6) as the case may be.

Outward ringing on the X line results from the operation of the RX key and relays (3) and (2). Relay (3) in energising releases (1) disconnecting the repeater, and operates the repeater cut-off relay. Similarly RY controls the outward ringing to the Y line.

For inward ringing and supervision, relays (11) and (12) are arranged to respond to the incoming 16 cycle ringing current. Relay (13) is energised by (11) and locks to an earth on relay (16), at the same time lighting the supervisory lamp XSL. (13) is released by the operation of (15) and (16) as the operator answers. The Y side supervision is operated in a similar manner.

It will be noticed that in this link circuit all speech path connections are made through multipled contacts on special relays. The latter are the North Electric Company's "Units" relays, which have an arrangement of springs giving a wiping contact. (See Fig. 3). This special provision has been found to be necessary to ensure that the efficiency of the repeaters is not decreased by contact losses in the auxiliary apparatus. The ordinary relay contact is liable to give trouble from the effects of the dust which is very prevalent in the plains of India, and experience has shown that in reducing the number of dirty contact faults the doubled wiping contact is by far the most successful system.

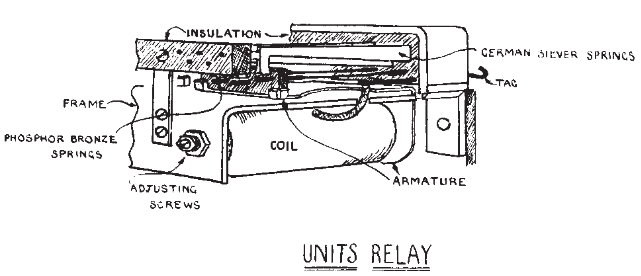


FIG. 3.

Network Selection Apparatus.—Simultane-

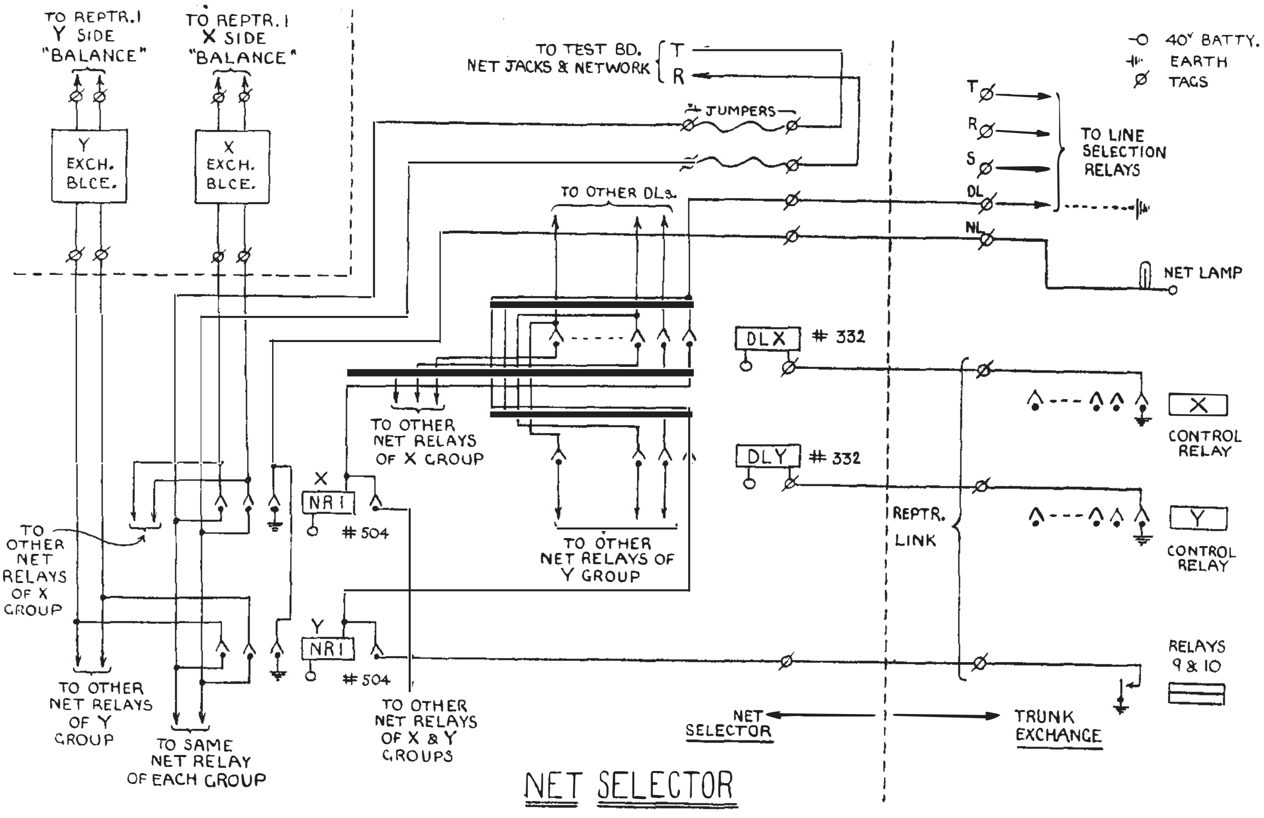

TO REPTR.I Y SIDE "BALANCE"
TO REPTR. I X SIDE "BALANCE"
Y EXCH. BLCE.
X EXCH. BLCE.
TO TEST BD. NET JACKS & NETWORK
T
R
JUMPERS
TO OTHER DLs.
40V BATTY.
EARTH
TAGS
T
R
S
DL
NL
TO LINE SELECTION RELAYS
NET LAMP
DLX
# 332
DLY
# 332
X CONTROL RELAY
Y CONTROL RELAY
TO OTHER NET RELAYS OF X GROUP
TO OTHER NET RELAYS OF Y GROUP
X
NR1
# 504
Y
NR1
# 504
TO OTHER NET RELAYS OF X GROUP
TO OTHER NET RELAYS OF Y GROUP
TO SAME NET RELAY OF EACH GROUP
TO OTHER NET RELAYS OF X & Y GROUPS
REPTR. LINK
RELAYS 9 & 10
NET SELECTOR
TRUNK EXCHANGE
NET SELECTOR

Fig. **4.**

ously with the connection of the line to the repeater link the associated balancing network is automatically connected to the " Balance " side of the repeater. A schematic diagram of the network selection circuit is shown in Fig. **4**, the apparatus itself being seen on the right of the network rack in Fig. **5**. The operation of the circuit is as follows:—

When the repeater link " Control " key is thrown to the X side, the control relay in the line selection circuit is energised and one of its contacts is used to operate the DLX relay in the net selector. The contacts of DLX are arranged to connect thirty " DL " wires through from the line selection apparatus to the network relays. As the selection key on the switchboard is pressed, the DL wire of the line selected is earthed, the corresponding net relay (NR) is operated by that earth and locks to an earth on relay (9) in the repeater link. After selection, the " Control " and " Selection " keys are normalled, and relay DLX is released. The operation of the network relay connects the line balance to the X "Balance" side of the repeater and also lights a lamp on the switchboard, over the line equipment concerned, to indicate to the operator that the network has been correctly selected. The Y side connection is made in a similar manner by the operation of DLY and the net relay in the Y group.

Release:—With the release of the repeater link, relays (9) and (10) are de-energised and the net relays are released. The relays used in the network selection circuits are the " Units " relays previously mentioned, thirty-two point " Tens " relays being used for DLX and DLY.

Balancing Networks.—The balancing networks are built up on the unit principle. The units of the network are mounted on a rack as shown in Fig. **5**, and cabled *via* a jumpering field on the rack to break-jack strips fitted on the trunk line test board. The cables terminate on the outer springs of the break-jacks, the inner springs being wired to tag-blocks in the test board as shown in Fig. **6**. Jumpers on these tag-blocks cross-connect the network

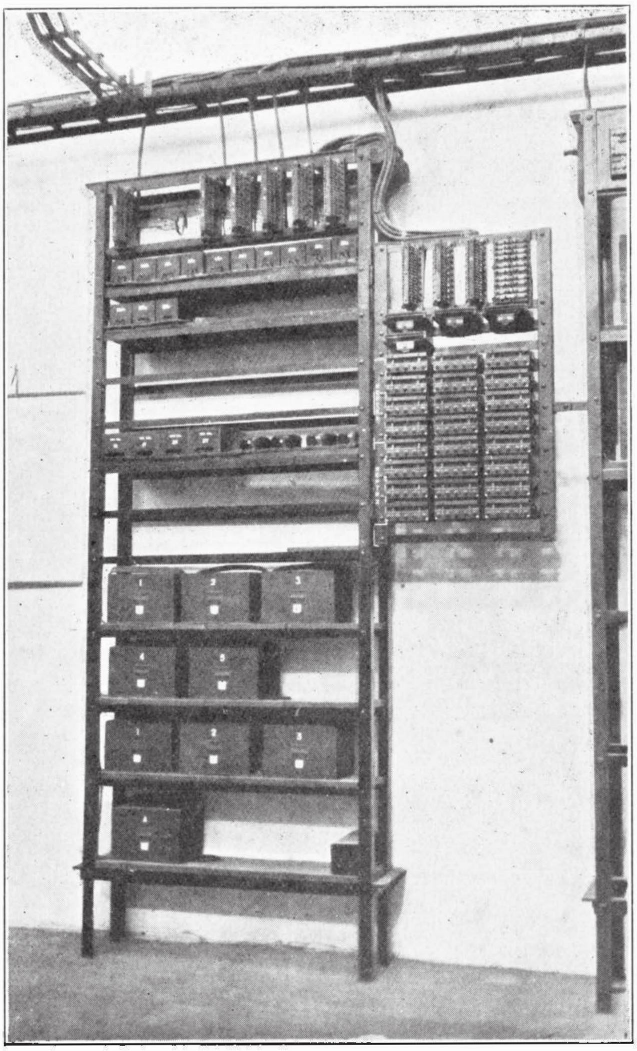


Fig. 5.—Network Rack and Selector.

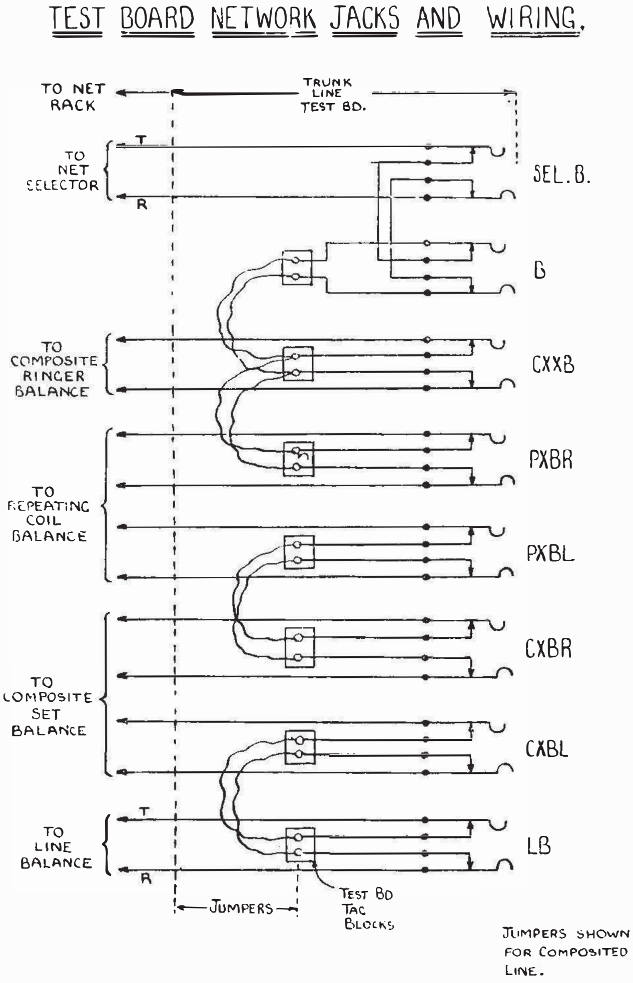


Fig. 6.

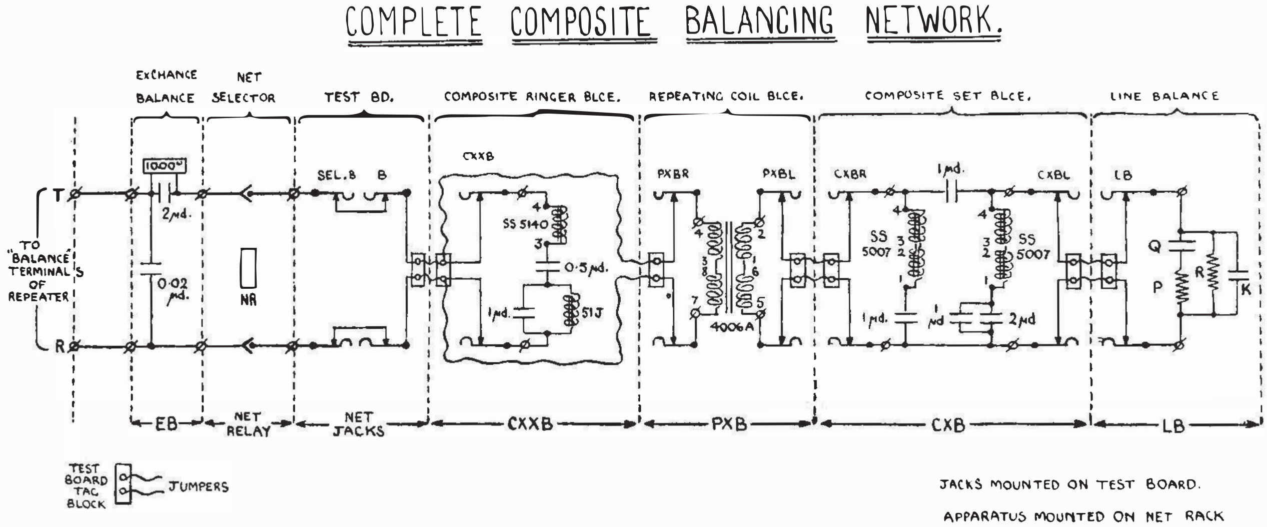


Fig. 7.

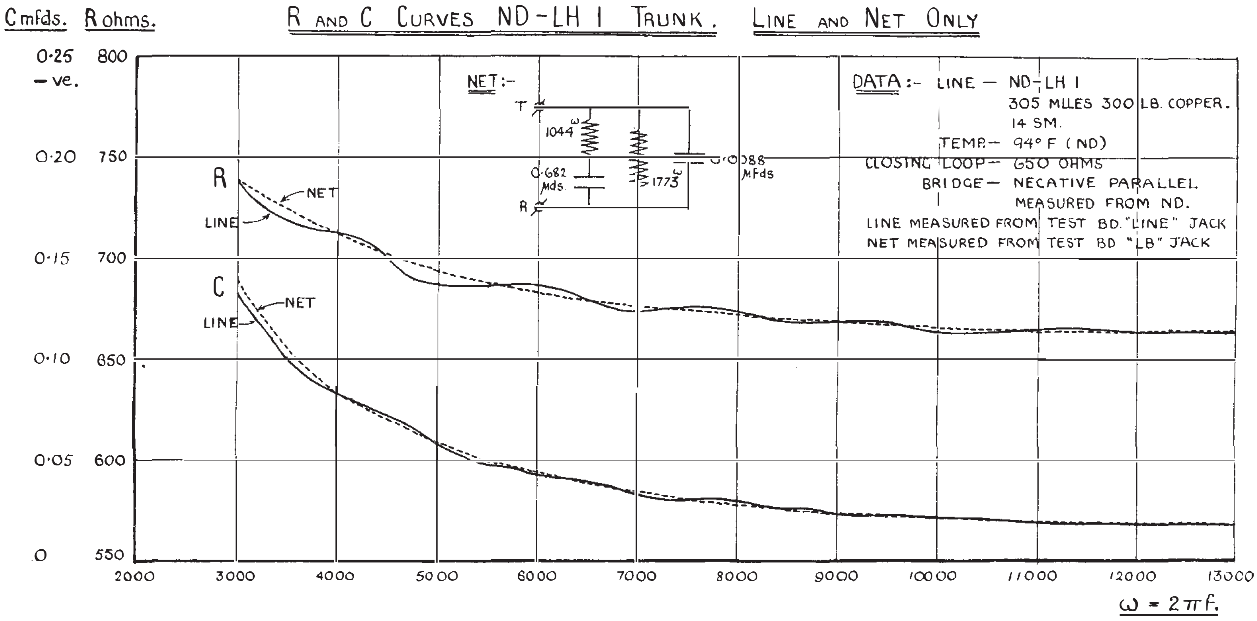


FIG. 8.

units as required for permanent line arrangements;—Fig. 6 illustrates the jumper connections on a composited line. For temporary line arrangements patch-cords plugged into the jacks remove or introduce the composite balancing units as required. For example,—a patch-cord from " Sel B " to " PXBR " and the second cord from " PXBL " to " LB " take the

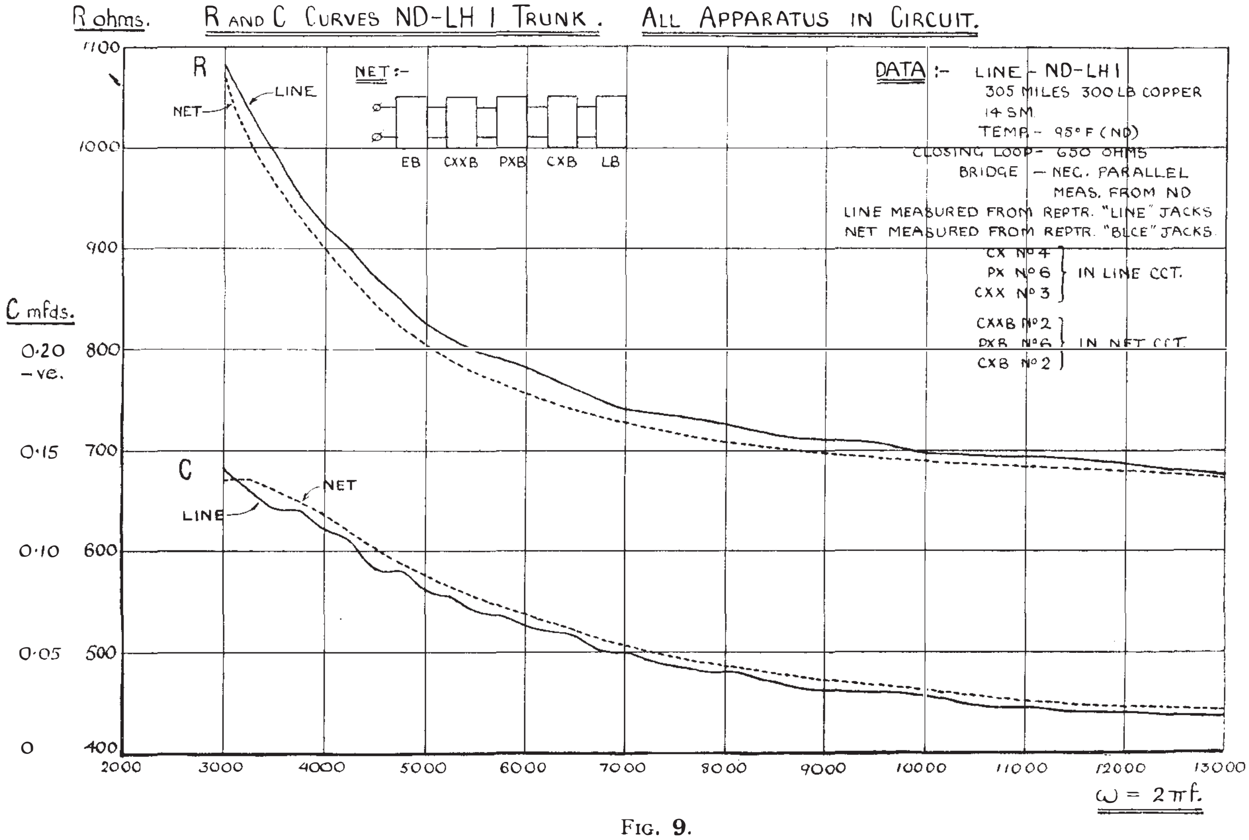


FIG. 9.

composite set and ringer balances out of circuit.

Fig. **7** shows a complete network on a composited line. The exchange balance "EB" in the leads from the repeater to the net selector balances the repeater link apparatus and exchange cabling, the remaining units in the chain balancing the various line apparatus. The line balance shown is of the "parallel"* type, the actual values of the components of a typical balance being given in Fig. **8**. The latter diagram and Fig. **9**, illustrate typical impedance curves of a composited trunk with and without its auxiliary apparatus. The curves in Fig. **8** are plotted from measurements made with a capacity A.C. bridge from the "Line" jack of the trunk line test board and the "LB" jack of the balancing network. Those in Fig. **9** are measured from the "Line" and "Balance" jacks of the repeater and indicate the degree of balance with all apparatus in circuit.

Singing-point tests taken on the line illustrated show a singing-point above the gain figure obtained on the fourth step of the potentiometer, *i.e.*, something over 15 T.U. As a check on balance conditions, singing point tests are made as a matter of routine in addition to the usual voltage, current, and gain measurements, etc., while special attention is paid to the operation and testing of auxiliary apparatus owing to the importance of the latter in the working of single long distance trunks.

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* *"Testing of Telephone Circuits and Apparatus with Alternating Curents," by E. S. Ritter and G. P. Milton, I.P.O.E.E. Paper No.* 110.

THE ROUTINE TRANSMISSION TESTING OF SUBSCRIBERS' INSTRUMENTS AT THE EXCHANGE AND AT THE SUBSCRIBERS' OFFICE.

A. HUDSON, B.Sc., A.C.G.I.F.C.

INTRODUCTION.—In the July, 1924, number of this Journal a description was given of apparatus, called a Volume Tester, for measuring the sending efficiency of a subscriber's instrument at the exchange without the knowledge of the subscriber and during the progress of an ordinary call. This apparatus, however, used by itself has serious limitations, when considered as a means of assisting maintenance. These may be briefly summarised thus:—

(1) The sending efficiency only is measured.
(2) The efficiency of the subscriber's talking is included.
(3) In the case of a P.B.X. there is uncertainty as to which instrument is being used.
(4) Calculations involving the circuit allowance of the subscriber's loop are necessary to determine the loss.

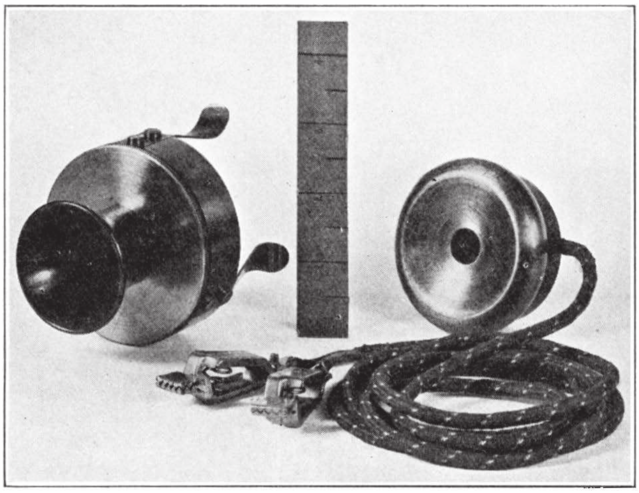
No. (2) can be an advantage when the instrument is used in another fashion, as will be described later.

Since the date of the first article a considerable amount of research has been carried out with a view to evolving a simple and rapid means of measuring the true efficiency of both the receiver and the transmitter in terms of the Department's standard without disturbing the subscriber's telephone. A considerable measure of success has been attained, and the value of the method proved in an extended series of tests made at Portsmouth and Willesden exchanges.

DESCRIPTION OF METHOD OF TEST.

The basic idea underlying the test is that of comparison with a standard. A standardised receiver is connected to the line terminals of the subscriber's installation and the A.C. voltage generated by this receiver is compared with that generated by the test transmitter and receiver, on being spoken into in turn. A valve voltmeter of the potentiometer type called a "Telephone Efficiency Tester," located at the exchange, is used for this purpose.

A standardised receiver and an artificial ear are the only pieces of apparatus which it is strictly necessary for the lineman to carry with him for the test, and in bulk the set is about 3″ diameter by 4″ long and weighs about 2 lbs. See the illustration.



Standardised Receiver and Artificial Ear.

The artificial ear is so named because when applied to a receiver it produces the same degree of diaphragm damping and modification of resonance as would be produced when the receiver is applied to a human ear. In this case the artificial ear has a mouthpiece attached to it on the reverse side to the receiver, acoustical connection being made by means of a number of small holes in the back of the artificial ear. This enables the lineman to talk into the standard receiver.

The artificial ears and standard type receiver so far used are not entirely satisfactory since they require frequent recalibration, but it is hoped as a result of further research shortly to produce types which will only require occasional calibration.

The method of use is then as follows:—

(1) The standardised receiver, which is of the electromagnetic type, is connected to the line terminals of the subscriber's instrument, the test receiver being on the hook. The test clerk at the exchange then adjusts the line current to some predetermined value, which is always the same, so that the equivalent of a 300 ohm local line is obtained. In the case of a line over 300 ohms battery is added to bring the current to the correct value.

(2) The lineman then counts 1, 2, 3, 4, 5, about 7 or 8 times, pauses and then repeats it into the artificial ear which is attached to the standard receiver. The test clerk measures the A.C. voltage delivered to the exchange during this talk by means of a constant deflection valve voltmeter. This he effects by setting the potentiometers of the voltmeter (which are arranged to give a range from 0 to 70 S.M. in 1 S.M. steps) to some value (given with the standard receiver) and noting the deflection obtained. All further measurements on the same test are then made by altering the potentiometers so as to obtain this deflection. This method thus gives the efficiencies direct in S.M.

(3) The lineman disconnects the standard receiver from the line and, taking the test receiver off the hook but *not* holding it to his ear, he repeats his talk into the transmitter at the same volume as before. The test clerk measures this voltage by adjusting the potentiometers.

(4) The lineman then cuts out the transmitter either by short-circuiting it for C.B. circuits or disconnecting the cells for L.B. circuits. He then applies the artificial ear to the test receiver and talks into it, again at the same volume. This voltage is also measured by the test clerk by adjusting the potentiometers.

The test should be made as quickly as possible in order that the lineman may be able to keep his volume constant, but where the test is interrupted, for instance, to change a transmitter or receiver a check on the standardised receiver is necessary.

Two or three minutes is about the time taken when the test is carried out by skilled men under favourable conditions.

Two calibration figures are required to determine the actual efficiencies of the instruments, those of the standard receiver in terms of the Department's standard receiver and the standard receiver plus artificial ear in terms of Department's standard transmitter. Call these two quantities " A " and " B " respectively. Let the potentiometer settings obtained by the test clerks be

" S " for the standard receiver.
" T " for the test transmitter.
" R " for the test receiver.

Then the transmitter efficiency will be

B + S − T worse than Department's standard; and for the receiver:

A + S − R worse than Department's standard.

When these expressions are negative the efficiencies are better than standard.

A + S and B + S will be constants for any combination of artificial ear and standardised receiver, so that it will be seen that the efficiencies are obtained very simply. Any case of low efficiency should be further investigated at the time of the test.

Very little difficulty has been experienced so far in carrying out the test with the linemen who have been employed. Careful training is necessary, but after about a week's experience it is found that they can generally be relied upon to give consistent results.

ACCURACY OF TEST.

Laboratory tests of the accuracy of this method are very difficult to carry out. The standard method of testing an instrument involves an elaborate cable balance, carried out six times by three different observers over a period of time of from 20 to 30 minutes. The new method uses one balance, with a talking period of about 15 seconds. This implies that only a limited degree of agreement of results by the two methods can be expected in the case of transmitters. From the nature of the test, however, it is apparent that the efficiency of the transmitter, at the time of the test, is obtained. It has been decided that the transmitter must be tested exactly as it stands without tapping or shaking in any way beforehand. The resultant figure will not necessarily be the same as that which would be obtained on removing the transmitter and re-testing it in the laboratory; the apparent error is of the order of $\pm 1\frac{1}{2}$ S.M. on the average.

In the case of the receiver, the errors are caused by factors different from those that govern the transmitter efficiency. On holding a receiver to an ear, the cap and diaphragm become warmed up much more quickly than the body of the receiver, with the result that the diaphragm is stressed, causing movement either towards or away from the magnet poles and thus altering the efficiency. When the receiver is placed on the artificial ear no such action can take place as the ear is at the same temperature as the surrounding air. The errors due to this cause are in the neighbourhood of 2 or 3 S.M. and will vary according to the clamping of the diaphragm.

Another source of error is line noise. The attenuating P.D. delivered to the exchange by the receiver is very small and may, in the case of a low efficiency receiver, be commensurate with the voltage of line noise. When the line noise voltage is sufficient to interfere with the test it may be considered that the noise is excessive and steps should be taken to eliminate it.

CIRCUIT ARRANGEMENTS.

The valve voltmeter set used at Portsmouth and Willesden is mounted so as to be readily portable and can be used in any exchange; it is self-contained as regards batteries, etc.

Another type suitable for installation in exchanges and to be used for routine testing is under design at the moment. The apparatus is mounted entirely on racks and is independent of the test desk, although it is proposed to use it in conjunction with the test desk.

From the nature of the test it will be apparent that a clear line, free from D.C. bridges, is necessary, but that apart from this the resistance of the line is immaterial. Consequently it is possible for the voltmeter set to be placed at a central exchange, serving several others *via* junctions. It is desirable that the A.C. loss due to the junctions should not exceed 5 S.M.

In the case of P.B.X.'s a double-plugged cord is used. Series indicators as used in cordless boards do not affect the test.

PROPOSALS FOR FUTURE USE.

The subscriber's output measuring set, which has been called the " Volume Tester," is most suited for observation testing, though it can be used for any case where the volume level of speech is required to be known.

It is proposed to install an experimental Volume Tester and a " Telephone Efficiency

Tester " at an exchange with a view to trying out various methods of using both sets. The volume tester will be used for observation purposes. In this way a check can be kept on the general level of volume in the exchange and cases of bad speaking investigated by checking the volume level of all calls made by the complainant.

With regard to the telephone efficiency tester the question of providing every internal lineman and fitter in the exchange area with a lineman's unit is under consideration, a test being made every time a subscriber's premises are visited, unless a visit has been made just previously.

The volume tester used in the above fashion provides an easy method of detecting faulty installations apart from subscribers' complaints.

The telephone efficiency tester enables the test clerk readily to test faulty and new installations, every lineman being available for making a test when required. Whether sufficient work of this nature will be carried out by each lineman to enable him to keep in practice from a talking point of view remains to be determined from the tests. The talking is an essential part of the test, and though apparently difficult to carry out correctly becomes comparatively easy when sufficient practice is given.

MEASUREMENTS OF THE ACOUSTICAL IMPEDANCES OF HUMAN EARS.

W. West, B.A., A.M.I.E.E.

SUMMARY. — In Part I. a method of measurement of the acoustical resistance of lightly absorbing surfaces is described, together with the results of tests on the resistance components of the impedances of normal (male) ears when held to a standard type ear-cap. Frequencies ranging from 370 to 2600 cycles per second are used.

Details of a similar method, applicable to the reactance component, are given in Part II., together with test results at frequencies of 500, 1100 and 1600 cycles per second.

Part III. contains comment on the results of the investigation, and is concluded by two appendices in which equations required in the text are derived.

1. *Introduction.*—An acoustical determination of the performance of a telephone receiver under working conditions demands a means for measuring the pressures developed with the receiver held in position either to a real ear, or to an artificial ear which is acoustically equivalent. In order that the latter alternative may be available, it is first necessary to obtain some data on which may be based a specification for the acoustical impedance of such an artificial ear, either as an average value, or at least as lying within the range of variation to which the acoustical impedances of normal ears are liable.

Hitherto the method employed has been to adjust the impedance of the artificial ear until the electrical impedance loop of a receiver held thereto resembles closely that of the same receiver when held to a real ear. This method, though not quantitative (in the absence of knowledge of the mechanical properties of the receiver) enables an adequate impedance match to be obtained at the resonant frequency of the receiver. The present investigation aims at a quantitative determination of the acoustical impedances of a reasonable number of normal (male) ears over a considerable frequency range. The methods employed use acoustical resonators, observations being made of the acoustical impedance at resonance.

It must be understood that the impedance measurements relate only to the condition when the ear is held to the Post Office standard receiver ear-cap, *i.e.*, to the impedance as viewed through the aperture of the ear-cap.

There are, of course, two components to the impedance, namely, resistance and reactance. The former is probably the more important in the testing of commercial receivers, since it plays a part in determining the magnitude of the pressures developed at resonance. The effect of the latter is to alter the frequency at which this resonance occurs.

Acoustical impedance is defined as the ratio of alternating pressure to alternating rate of volume displacement, *i.e.*, if a piston of area S is vibrating with velocity v and a pressure p is developed at its surface due to its contact with the medium (air), the acoustical impedance, Z equals $\frac{p}{Sv}$ which is in general a complex quantity. The analogue to the electrical circuit is: p to E.M.F. and Sv to current, or v to current density. [Note that a mechanical impedance differs since it is the ratio of total force to linear velocity, *i.e.*, $\frac{S.p.}{v}$. The difference of these two conceptions of impedance lies in the fact that in some problems, as in the present investigation, pressures are measured without reference to the area over which they are applied, whereas in others it is the total force only that is dealt with. In either case the power developed equals $S.p.v$ where p and v are the in-phase components. Thus a Mechanical impedance = impedance per unit area multiplied by the area (dimensions $M\,T^{-1}$) and an Acoustical impedance = impedance per unit area divided by the area (dimensions $M\ T^{-1}\ L^{-1}$). In what follows the word " impedance " is used to refer to the acoustical impedance, unless otherwise defined.]

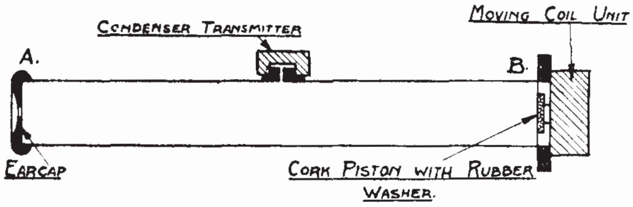


Fig. 1.

Part I.—Resistance Component.

2. *Apparatus and Method of Test.*—Apparatus was assembled as shown in Fig. 1. A brass tube, 3 ft. long by $2\frac{3}{4}$ ins. internal diameter and $\frac{1}{8}''$ wall, was closed at one end, A, by a standard ear-cap, from which the threaded portion had been removed, and at the other end, B, by a moving coil unit driving a cork piston $2\frac{1}{4}$ ins. in diameter. The seal round the rim of the piston was effected by thin sheet rubber. At the centre of the length of the tube a hole about 3 mm. in diameter communicated with the diaphragm of a condenser transmitter, which was connected through an amplifier to a voltmeter.

The method broadly consists in applying at end A in turn the impedance to be measured, and two known impedances and adjusting the frequency each time to give the maximum value for E (the voltage output from the condenser transmitter).

If it be assumed that the motion of the piston is the same in each case, sufficient data are available to evaluate separately the absorption due to the tube and that due to the impedance under test, and thence the non-reactive component of this impedance. One of the known impedances was simply obtained by sealing the hole in the ear-cap with a plug of plasticine or lead, a condition sufficiently close to that of an infinite resistance. Others were used as described in the following section.

The assumption that the strength (S.v) of the source of sound remained constant is justified by its construction and by the fact that the absorptions of the impedances tested were small as compared with that in the tube (which was found to be largely due to the rubber seal at B). The reactive components also necessitated only very slight alterations in frequency (less than 0.5%) for tuning to resonance.

3. *Calibrations.* — The calibration of the apparatus consists in determining the absorption within the tube, since when this is known a simple comparison of the voltages when end A is closed, and opened to the impedance under test, respectively, suffices to determine the resistance component of this impedance.

For this purpose it was decided to attempt to obtain the condition of a semi-infinite, rigid-walled tube leading from end A of the resonator tube; this would provide a known standard acoustical resistance. With this end in view a 12 ft. length of $\frac{3}{8}''$ (internal diameter) brass pipe was obtained.

A bundle of 24 strands of medium weight darning wool (varying in length between 1 ft. and 4 ft. in order to offer gradually increasing absorption) was drawn through to the far end of the pipe, and the near end was provided with a small plasticine flange for sealing to the ear-cap at A. A test for reflection effects from the far end was made at each frequency used, by tuning to resonance and observing the value of E (output of condenser transmitter) while the wool bundle was drawn back through the pipe for a distance greater than half a wave-length. In no case could any variation be detected and no change was observed when the far end was closed and opened.

With this tube in position at end A, then, the reflection factor for amplitude at end A of the resonator tube is* $g_1 = \dfrac{S-\sigma}{S+\sigma}$ where S = sectional area of main tube and σ that of the pipe, *i.e.*, $g_1 = 0.964$. If it be assumed that the absorption in the main tube is concentrated at end B, where most of it undoubtedly lies, it can be allowed for by considering that the reflection factor at end $B = g_0$ and that there is no loss in the tube except at the ends.

It can be shown, as in Appendix I., that at resonance (having a pressure loop at the centre of the tube) the ratio D of the value of the pressure on the condenser transmitter (or the voltage output) with the test resistance at A, to the value with the end stopped ($g = 1$) is given by

$$D = \frac{(1-g_0)(1+g_1)}{2(1-g_1 g_0)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (a)$$

The calculated value of g_1 assumes that the velocity of the wave is unchanged after its entrance into the pipe; no sensible error is to be expected from this cause, but it was thought desirable to obtain an alternative method of calibration to verify results obtained with the pipe. The method adopted depends on altering the reactance at end A, leaving the resistance unchanged (infinite). The ear-cap at end A was removed and a brass cup (equivalent to a 1 cm. extension to the tube) was used to terminate the tube. The cup had $\frac{1}{8}''$ walls and the flat surfaces were faced. A test was made by smearing the end of the tube with a little mineral jelly, holding the flat face of the cup to the end of the tube with strong hand pressure, tuning to resonance and noting the voltage E_0. The cup was then reversed and held in a similar manner, thus extending the length of the tube by the depth of the cup, namely, 1 cm.; the voltage E_1 was observed without altering the frequency.

It is shown in Appendix I. that if $\dfrac{E_0}{E_1} = F$ and if $\dfrac{(F^2-1)^{\frac{1}{2}}}{\tan kl} = K$, where l is the length (1 cm.) added to the tube and $k = \dfrac{\omega}{c} = \dfrac{2\pi}{\lambda}$

$$\text{then} \quad g_0 = \frac{K-1}{K+1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (b)$$

The following table shows the results of calibrations carried out by these two methods:—

TABLE I.

ω	*fcy.*	Equation (*a*)		F	Equation (*b*)		
		D	g_0		*tan k*	K	g_0
2300	370	1.26	0.87	1.38	0.068	13.2	0.86
4700	750	1.16	0.795	1.53	0.138	8.5	0.79
7020	1100	1.16	0.795	2.0	0.208	8.3	0.785
9370	1500	1.11	0.715	1.98	0.282	6.05	0.72

The agreement in the values of g_0 so obtained is close. These values were lower than was expected; that this feature was largely due to the rubber washer was shown when, later in the investigation, the rubber was coated with a smear of jelly and it was found that the values of g_0 then exceeded 0.9.

4. *Test Results.*—The procedure of test was as follows:—A Bell receiver was first held to the ear to be measured in order that the sensation of normal pressure and position might be memorised. The ear was then placed against the ear-cap at the end of the tube, and the voltage E_1 at peak of resonance was noted. The end of the tube was then closed by a plug covering the aperture of the ear-cap and the voltage E_0

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* *c.f. Rayleigh § 351, p. 331. Equation 9.*

at peak of resonance again noted. From the value $D=\frac{E_1}{E_0}$ and from the value g_0 obtained from calibration, the value of g_1, due to the absorption by the ear, was calculated from equation (a).

It is shown in Appendix I. that the acoustical resistance of the ear is

$$R=\frac{\rho c}{S}\left(\frac{1+g_1}{1-g_1}\right) \quad \text{(C.G.S. units)}$$

where ρ = density of air and c = velocity of sound in air ($\rho c=40.8$) and S = sectional area of the tube = 38.3 sq. cms.

Since slight variations in the value of g_0 were observed from time to time; check tests of this value were made at intervals throughout each series of tests on individual ears. The results of series of tests at five different frequencies, each series including about twelve ears, are summarised in Table II. A series of tests on twelve additional ears was also made at 1100 cycles per second and included a wide range of ages, since it was thought that there might be variations in resistance with the age of the ear. No such variations were, however, observed, and the results were found to be in close agreement with those recorded in Table II.

TABLE II.

Frequency.	*Extreme Resistances.*	*Mean Resistance.*
370	100—300	175
745	90—350	175
1100	105—190	140
1500	80—145	105
2600	13—125	36

PART II.—REACTANCE COMPONENT.

5. *Apparatus and Method of Test.* — The resonator tube used for the Resistance tests was deliberately made moderately large in order to reduce the effects of different reactances at end A. It was therefore unsuitable for Reactance tests, and fresh apparatus was assembled. A ½ inch diameter tube, about 1 ft. long, was terminated at one end by a standard receiver ear-cap, and at the other end by a plasticine plug with two small holes on opposite sides of the tube, communicating respectively with a condenser transmitter and a watch type receiver, used as a source of sound.

In outline the method consists in adjusting the frequency to a resonance of the tube with the reactance under test at the end of the tube, measuring the frequency, and comparing its value with those obtained when a variable, calculable reactance is used. This calibrating reactance was made in the form of a short length of 1.75 cm. diameter, internally threaded brass cylinder, with a threaded brass plug carrying a graduated rod from which the position of the plug in the cylinder could be read. The cylinder was held against a standard receiver ear-cap, a plasticine seal being used at the joint, and the volume contained, at different positions of the plug, was measured by admitting water through the hole in the ear-cap from a burette. The volume could be varied from 0.5 to about 10 c.c.

It is shown in Appendix II. that the (elastic) reactance is $X=\frac{-\rho c}{kQ}$ where Q is the volume and ρ, c and k have the same meaning as previously employed. It remained therefore to determine the reactance of the ear in terms of the volume Q.

Accordingly the cylinder was placed in position on the ear-cap, the peak of resonance observed from the condenser transmitter output, and the frequency measured. This value was plotted against the corresponding value of Q. The cylinder was then replaced by the ear under test, held with normal pressure, and the frequency at peak of resonance again observed. The value of Q was obtained from this frequency reading from the calibration curve.

6. *Test Results.*—Test series were carried out on about 12 normal ears at frequencies near 1100 and 1600 cycles per second. At 1100 cycles per second the mean value of Q = 3.3 c.c. ($X=-61$), the extremes ranging from 1.0 to 5.0 c.c. At about 1600 cycles per second the mean value of Q was 3.8 c.c. ($X=-37$), the extremes ranging from 2.0 to 5.0 c.c. It was further observed that when resistance damping, equivalent to that of a normal ear, was permitted, the calibrating reactance values were not appreciably affected.

A test series was next carried out at about 500 cycles per second, and it was found that many ears gave a negative value of Q, *i.e.*, a mass reactance* at this frequency. In order to confirm this phenomenon an alternative method was sought.

Accordingly a method was used employing mechanical resonance (instead of acoustical) and aural detection of the resonant frequency (instead of instrumental). The diaphragm of a Bell receiver was loaded at its centre with a mass of lead to reduce its resonant frequency to the neighbourhood of 500 cycles per second. This receiver was then held to the ear and the frequency adjusted to resonance, as judged by an observer listening externally, and the adjustment was then made again with the ear under test as judge of the resonant frequency. Calibration was carried out by means of the adjustable cylinder previously used, there being no difficulty in ascertaining the resonant frequency by listening externally. With some ears there was also no difficulty in determining the resonant frequency and agreement between both methods was good. The range in the values of Q so obtained extended from 0 to 3.5 c.c. With other ears, however, (about an equal number) there was considerable difficulty and there is no doubt that, as judged by either method, two resonant peaks existed, one above and one below normal. This phenomenon of double resonance may be observed when two resonant systems, whose natural frequencies are equal, or nearly so, are coupled together. It is illustrated by an experiment of Mallett and Dutton (*J.I.E.E.*, Vol. 63, May, 1925, p. 510, Fig. 12), who observed the acoustic output from a Bell type receiver at frequencies in the neighbourhood of the fundamental resonance, when the back of the diaphragm was exposed to a closed air column whose length was adjustable.

It was concluded therefore that a non-reactive impedance or a mass reactance at this frequency was obtained with some ears (this effect is discussed in Appendix II.) and a further test series was carried out on the resonator tube—this time under two conditions with each ear, namely, normal pressure and an increased pressure between ear and cap, (in order to ascertain the effect of leakage of sound). The results showed that with normal pressure a mean value of $Q = -0.5$ c.c. with a range of about ± 4 c.c. was obtained, but with increased pressure the mean value was $+1.7$ c.c. and the range about 0 to 4 c.c.

The results at normal pressure are very variable, as may be expected from the fact that these are critical to ear pressure, and an estimation of normality by sensation is necessarily somewhat crude. It is not therefore to be expected that an individual ear will give very consistent results on repetition. There is also the presence of the slot in the standard ear-cap, which may occupy any position relatively to the ear, and thus adversely affect consistent observations on an individual ear.

PART III.—COMMENT.

7. No attempt has been made to ascertain the nature of the forces operating to absorb sound in any individual ear. It is probable that the absorption is to a large extent accounted for by transmission of vibrations into the exposed flesh, from the nature of which it is to be expected that the extent of penetration will be small. The expenditure of energy can only be considered as useful in so far as it is located at the drum of the ear. From the observed differences in absorption which are liable as a result of slight differences in the position of the ear relative to the cap, it may be inferred that appreciable absorption takes place at the outer ear. The amount of sound energy that escapes into the outer air is not considered to be appreciable when there is a normal pressure between receiver and ear. It is shown, however, in *Appendix* II. that a small leakage can have a very considerable effect on the reactance component, and it may therefore exert an indirect influence on the resistance component. For example, if the leakage is such that its mass reactance is equal to the elastic reactance of the enclosed air chamber, a condition of resonance obtains, which has the effect of creating a larger impedance at the opening of the ear-cap. Under this condition the quantity of sound which enters the chamber is reduced and a smaller absorption is to be expected. The reactance component for an average ear is found to become zero at a frequency

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* *The terms " Mass Reactance " and " Elastic Reactance " may conveniently be used to describe positive and negative acoustical reactances; c.f. " Inductive and Capacity Reactances."*

of about 500 cycles per second, and it is observed further that, at frequencies in this vicinity, the absorption is low and the variations with different ears are somewhat large, as may be expected when a critical effect such as resonance is introduced.

It seems not improbable that a similar effect may account for the high values of absorption observed at 2600 cycles per second. Such an effect would involve resonance of the elastic reactance of the air chamber with a mass reactance at the opening at the ear-cap, resulting in an abnormally low impedance at this opening. The necessary data to confirm this supposition are not at present available.

Although the variations in impedance appear to be accountable to a great extent on purely acoustical grounds, it is not to be expected that the mechanical properties of the texture of the ear can be ignored. During the investigation two ears, which were abnormal in that their hearing faculties were known to be below normal, came under observation. In both cases the impedances were found to be abnormal, one giving an exceptionally high value and the other an exceptionally low value of absorption at 1100 cycles per second. The former was also tested for reactance and was found to give a mass reactance at a frequency where normal ears all gave an elastic reactance.

It should be noted that the resistance and reactance components should be considered as acting in parallel. This may be seen from the manner in which the tests were carried out. It follows therefore that the rate of absorption of energy by the ear may be found from the equation: Power $= \frac{p^2}{R}$ where p = applied sound pressure and R is the resistance component of the impedance of the ear. It does not, of course, follow that this figure represents the rate of expenditure of energy in doing useful work.

APPENDIX I.

Acoustical Impedances applied to Tube Resonators.

a. With reference to Fig. **2**, suppose first that end A of a tube of sectional area S is closed by a partially absorbing plug, the reflection factor for pressures or velocities at this end being g.[*] Let the source of sound at end B be represented by a piston moving with velocity = $V_0\epsilon^{i\omega t}$. Suppose that the absorption along the tube and at end B is negligible as compared with that at end A. The length x of the tube refers to the distance between surfaces at which reflection takes place without change of phase.

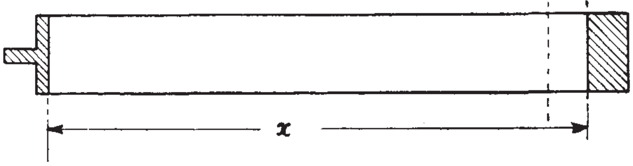

FIG. **2.**

The air velocity at B = piston velocity

$$= V_0\epsilon^{i\omega t}.$$

The pressure at B of the first wave (B to A)

$$= \rho c V_0\epsilon^{i\omega t}.$$

The pressure at B of the second wave (A to B)

$$= g\rho c V_0\epsilon^{i(\omega t-2kx)}.$$

The pressure at B of the third wave (B to A)

$$= g\rho c V_0\epsilon^{i(\omega t-2kx)}.$$

and so on.

$$\therefore \text{ Total pressure at B} = \rho c V_0\epsilon^{i\omega t}\left\{1+2g\epsilon^{-2ikx}+2g^2\epsilon^{-4ikx}+\ .\ .\ .\right\}$$

$$= \rho c V_0\epsilon^{i\omega t}\left\{\frac{1+g\epsilon^{-2ikx}}{1-g\epsilon^{-2ikx}}\right\}$$

Whence the impedance at B $\left(= Z = \frac{p}{Sv}\right)$

$$Z = \frac{\rho c}{S}\left[\left\{\frac{1-g^2}{1+g^2-2g\cos 2kx}\right\} - i\left\{\frac{2g\sin 2kx}{1+g^2-2g\cos 2kx}\right\}\right] \quad \text{.............(1)}$$

This equation applies to the impedance at B or at any section of the tube half a wave-length therefrom. It is capable of a number of useful applications, the first of which is to determine the relationship between the factor g and the acoustical resistance R at end A.

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[*] *See previous article in this Journal on the Measurement of Absorption of Sound, Vol. 20, Part 2, July, 1927, p. 127.*

If x is put $=0$, $$R=\frac{\rho c}{S}\left(\frac{1+g}{1-g}\right) \text{..............(2)}$$

Further applications will be made in Appendix II.

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b. Next suppose that there is absorption at B as well as at A, the reflection factor at B being g_0. A general equation can be obtained on the same lines, but for the present purpose it is only necessary to obtain the result when the tube is in resonance, *i.e.*, $\epsilon^{-2ikx}=1$.

As before, by summation of the separate waves, the pressure at B is proportional to

$$1+g+gg_0+g^2g_0+g^2g^2_0+\ .\ .\ .\ .\ .$$

$$i.e.,\ p=P\ (1+g)\ (1+gg_0+g^2g_0{}^2+\ .\ .\ .\ .)$$

(Where P is a constant including a term for the velocity of piston).

$$\therefore\quad p=\frac{P(1+g)}{(1-gg_0)} \text{.................................(3)}$$

If the absorbing plug at A be replaced by a non-absorbing surface ($g=1$), the pressure at B becomes

$$p^1=\frac{2P}{1-g_0}$$

$$\text{The ratio } \frac{p}{p^1}=D=\frac{(1+g)\,(1-g_0)}{2\,(1-gg_0)} \text{...........(4)}$$

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c. If now the absorbing surface be retained at B, and a non-absorbing surface be placed at A, the general equations for the velocity and pressure at B, for any value of x, may be derived as follows:—

As before, the piston velocity $=V_0\epsilon^{i\omega t}$.

The air velocity at $B=v=V_0\epsilon^{i\omega t}-V_0\epsilon^{i(\omega t-2kx)}$
$+gV_0\epsilon^{i(\omega t-2kx)}-\ .\ .\ .\ .$

$$=V_0\epsilon^{i\omega t}\left(\frac{1-\epsilon^{-2ikx}}{1-g_0\epsilon^{-2ikx}}\right)$$

[Note that this is not the same as the piston velocity, since the supposition of absorption by the piston presumes relative motion between piston and air.]

The pressure at B =

$$p=\rho cV_0\epsilon^{i\omega t}\left\{1+\epsilon^{-2ikx}+g_0\epsilon^{-2ikx}+g_0\epsilon^{-4ikx}+\ .\ .\ .\right\}$$
$$=\rho cV_0\epsilon^{i\omega t}\left\{\frac{1+\epsilon^{-2ikx}}{1-g_0\epsilon^{-2ikx}}\right\}$$

[The acoustical impedance of the tube at B is therefore

$$Z=\frac{\rho c}{S}\left(\frac{1+\epsilon^{-2ikx}}{1-\epsilon^{-2ikx}}\right),\ \text{independent of } g_0.]$$

For a prescribed constant motion $V_0\epsilon^{i\omega t}$ of the piston

$$p=\rho cV_0\epsilon^{i\omega t}\left\{\frac{(1-g_0)(1+\cos 2kx)-i(1+g_0)\sin 2kx}{1+g_0{}^2-2g_0\cos 2kx}\right\}$$

The modulus is proportional to

$$\left[\frac{2(1+\cos 2kx)}{1+g_0{}^2-2g_0\cos 2kx}\right]^{\frac{1}{2}}$$

Let F = ratio of this value when $\cos 2kx=1$ to that when $\cos 2kx=\cos 2kl$.

$$\text{Then } F=\left(\frac{2}{1-g_0}\right)\left[\frac{(1-g_0)^2+4g_0\sin^2 kl}{4\cos^2 kl}\right]^{\frac{1}{2}}$$
$$=\left[1+\left(\frac{1+g_0}{1-g_0}\right)^2\tan^2 kl\right]^{\frac{1}{2}} \text{...............(5)}$$

$$\left.\begin{aligned}\therefore\quad \frac{[F^2-1]^{\frac{1}{2}}}{\tan kl}&=\frac{1+g_0}{1-g_0}=K\\ \text{and } g_0&=\frac{K-1}{K+1}\end{aligned}\right\} \text{..................(6)}$$

APPENDIX II.

Acoustical Impedances applied to Helmholtz Resonators.

d. Equation (1) of Appendix I. may be used to find the acoustical (elastic) reactance of a small, rigid walled chamber whose dimensions are small as compared with a wave-length—such for example as the calibrating cylinder referred to in Part II. of the text. When $g=1$, the impedance at end B of the tube is

$$Z=-\frac{i\rho c}{S}\cot kx.$$

For small values of kx, $\cot kx=\dfrac{1}{kx}$.

$$\text{Whence } Z=-\frac{i\rho c}{Skx}=-\frac{i\rho c}{kQ} \text{................(7)}$$

where Q = volume of the chamber.

[The operator i signifies pure reactance and the negative sign that the reactance is elastic.]

The equation applies to a chamber of any shape, provided that each dimension is small as compared with a wave-length, and that absorption is inappreciable.

If now the piston at B is replaced by a thin wall with a small aperture, diameter d, the acoustical mass reactance of the aperture is $+\dfrac{i\rho\omega}{d}$

The reactance at the aperture (dropping the operator i) is therefore

$$\left.\begin{aligned} Z &= \frac{\rho\omega}{d} - \frac{\rho c}{S}\cot kx \\ &= \frac{\rho\omega}{d} - \frac{\rho c}{kQ} \text{ (for small values of } kx) \end{aligned}\right\} \quad \ldots(8)$$

(This equation is given by Richardson, Proc. Phys. Soc., Vol 40, Part 4, June 15, 1928).

At resonance the impedance at the aperture becomes zero (if dissipation is neglected), and

$$\frac{\rho\omega}{d} = \frac{\rho c}{kQ}$$

$$\text{or} \quad \omega^2 = \frac{dc^2}{Q} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

The usual formula for resonance of a simple resonator.

e. The effects of leakage of sound, when an ear is held to an ear-cap, on the reactance at the ear-cap may be deduced by substituting for the mass reactance of the leakage sound, that of an aperture, diameter d, in a thin wall. Let this wall then occupy end A of the tube.

If absorption at the aperture is neglected, reflection will take place as if from a solid surface (*i.e.*, the magnitude of the reflected wave= that of incident wave). Owing to reactance at end A this surface will not be at A, let it lie at C, where $AC=x^1$. Now when $x=x^1$, since the impedance at C is, by hypothesis, infinite resistance, the tube becomes a Helmholtz resonator, whence from (9) $x^1 = \dfrac{d}{Sk^2}$, and the impedance at A is, in general.

$$Z = -\frac{i\rho c}{S\tan k(x-x^1)}. \quad \ldots\ldots\ldots\ldots\ldots\ldots(10)$$

The tube resonates (giving a maximum pressure at end B) when $x - x^1 = \dfrac{n\pi}{k}$, where n is an integer.

Two important effects of leakage sound may be deduced: (1) The presence of leakage raises the frequency of resonance of the tube, since $k = \dfrac{n\pi}{x - x^1}$, which is greater than the value at resonance with no leakage, namely, $k = \dfrac{n\pi}{x}$; and (2) This effect of leakage becomes greater as the mass reactance of the aperture, $\dfrac{\rho ck}{d}$, becomes smaller as compared with the elastic reactance of the air chamber, $\dfrac{\rho c}{kQ}$; that is as k^2 becomes smaller as compared with $\dfrac{d}{Q}$.

Suppose, as a numerical example, that the tube is terminated by a chamber whose volume is 4 c.c., and which has an aperture 0.04 cm. diameter in one wall. The reactance of the chamber is $X = \dfrac{\rho c}{kQ_0}$ where $Q_0 = 4 - Sx^1 = 4 - \dfrac{0.04}{k^2}$.

When therefore $k=0.1$ (540 cycles per sec.) $Q_0=0$ and the impedance is non-reactive.

When $k < 0.1$ the impedance has mass reactance.

When $k=0.2$ (1080 cycles per sec.) $Q_0=3$ c.c.

When $k=0.4$ (2160 cycles per sec.) $Q_0=3.75$ c.c.

This example gives results which are quantitatively similar to the observed reactances of the space included between the ear and the standard cap.

RENEWAL OF LAND LINES AT FAYAL, AZORES.

AN engineering operation of an interesting character has been carried out recently at Fayal, Azores. These islands in the Atlantic, belonging to the Republic of Portugal, are conveniently placed on the routes of several Transatlantic cables. Two of these cables, led in and out at Fayal, belonged originally to the German Government and were taken over after the Armistice as part of the reparations, one by the British Administration (this cable being known to-day as " Imperial No. 1,") whilst the other is operated for the French Government.

The land lines at Fayal associated with these two submarine cables were in urgent need of renewal and the position was becoming the more serious because of earthquake disturbances,—a frequent visitation at the Azores. When it became known that the British and French land-line cables were to be renewed, it was ascertained that the Eastern Telegraph Company also desired to have similar work done, and it was agreed that the British Post Office Engineering Department should undertake the whole of the operations. This included the design, laying and testing of the British and French armoured cables, and also the laying and testing of two armoured cables for the Eastern Telegraph Company, all the work to be done in a common trench; the total length concerned being $1\frac{3}{4}$ miles.

The works estimate was prepared in London and dependence placed upon such information as could be obtained by correspondence with local representatives of the Cable Companies in regard to measurements, wayleaves, contours, sub-soil, pavings, obstructions, transport, labour, and other details attending the construction of underground work in a foreign country;—matters which, though not troublesome in like circumstances at home, may loom large when there is no one to whom to appeal, or Acts of Parliament to invoke!

The cable designed for the replacement of the British and French land lines is of a special type and was supplied by Messrs. Siemens. A section of the cable is shown in Fig. 1. It consists of three separate tri-core lead covered cables formed into one armoured cable of an overall diameter of $2\frac{1}{4}''$. The conductors are made up of a strand of seven copper wires of equal diameter, the weight and resistance per statute mile of each stranded conductor being 300 lbs. and 3.03 ohms respectively. Each stranded conductor is covered with four lappings of paper, the outermost being coloured red, blue

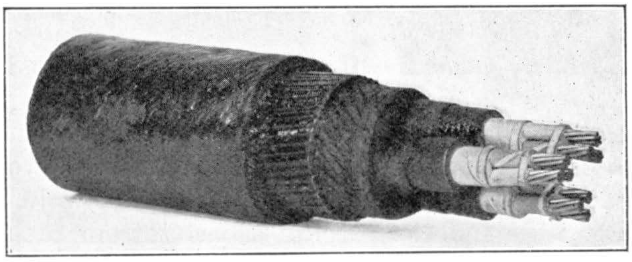


FIG. 1.—SECTION OF CABLE.

or white for identification of the individual cores. The three conductors are so laid up as to form a compact and cylindrical cable and finally wrapped overall with two lappings of insulating paper. The cable thus formed is lead sheathed and covered first with a coating of compound, then with a double wrapping of impregnated paper and a final coating of compound. The three lead sheathed cables are laid up on a central core of tarred jute yarn, wormed and served with sufficient tarred jute yarn to receive the sheathing of 45 galvanised iron wires of No. 12 S.W.G., each of which had been separately coated with preservative compound before application to the cable. The armouring is covered overall with two servings of stout three-ply tarred jute yarn alternating with two coats of compound, and the finished cable whitewashed. The electrostatic capacity from each wire to earth is 0.3 microfarads per mile, and the insulation resistance 5,000 megohms per mile per wire.

A special type of jointing coupling has also been used in connection with the work and details of this fitting are shown in Fig. **2**. It consists of a cast iron box, with specially designed conical clamp fittings at each end to grip the armouring wires. Any strain coming on the armouring of the cable is transmitted across the box by means of mild steel bolts. Three lead sleeves are accommodated in the jointing coupling. The joints are staggered as shown in Fig. **2** and ordinary wiped joints made in each case. In order to maintain high insulation, each of the lead sleeves is filled with paraffin wax, and when the joints have been completed, the box itself is filled with compound. An earthing bond is provided in order to maintain continuity between the armouring of the lengths of cable on each side of the coupling.

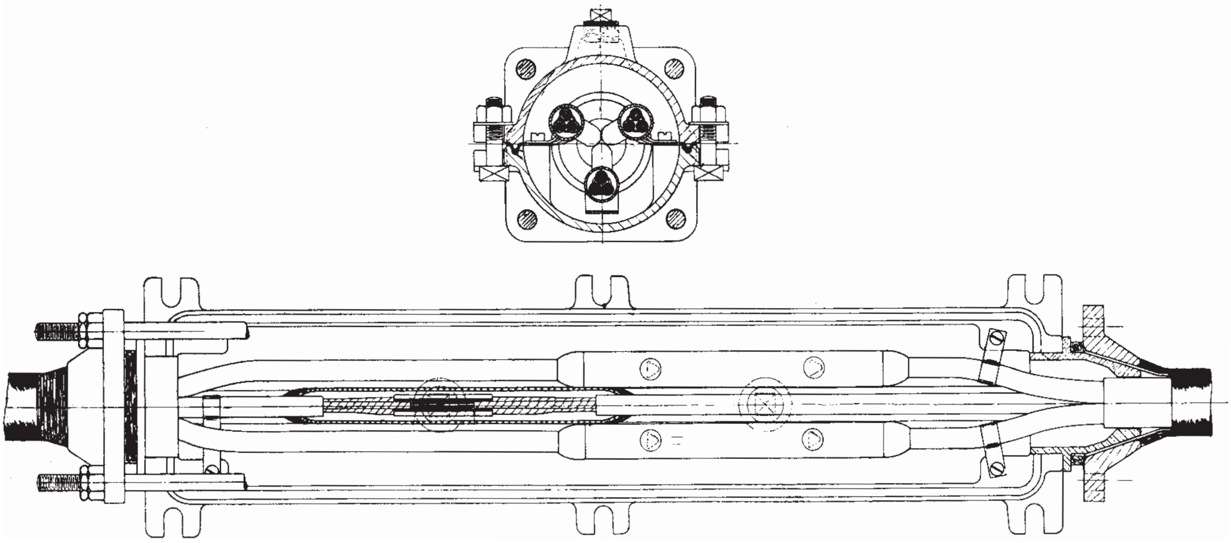


FIG. **2**.—STRAIGHT JOINT BOX.

A special type of terminal box has also been designed for the termination of the British and French land lines at the cable hut and cable station respectively. An open and closed view of the terminal box is shown in Fig. **3**. The three individual lead covered cables are brought out from the armoured cable and led into separate brass glands at the bottom of the box. The paper cables are sealed with compound at the back of an ebonite panel. Each conductor is brought through this panel by a long ebonite bush to the front portion of the box so that leakage is prevented, and the terminations to the apparatus made of single leads of "Maconite." The arrangement proved an efficient and accessible termination of the armoured cables.

The transport arrangements at Fayal are of the most primitive order; practically all haulage work is done by bullock teams. It is understood that a mechanical tractor was once left at Fayal by a firm of contractors, but the alleged reason for this is that the taxes imposed by the public authority were so heavy that it paid the contractors to leave the machine behind!

It was impossible to rely upon any local help in the supply of tools and small stores for the work, and all such items had to be shipped from England. The term "Subsidiary stores" became an important matter; there was no convenient section stock stores round the corner from which deficiencies could be made good!

There is no direct steamship service between London and Fayal and the bulk measurement of 65 heavy drums of cable, 30 bulky cases and many loose bundles was considerable. The question also arose as to the possibility of shipping all the goods on one small steamer. If not, a delay of a month or so between the arrival of different steamers would be exasperating, and probably the items most urgently required would miss the first boat. Luckily, the Post Office stores were the first to be handled at the docks and all were safely stowed under hatches on the same steamer.

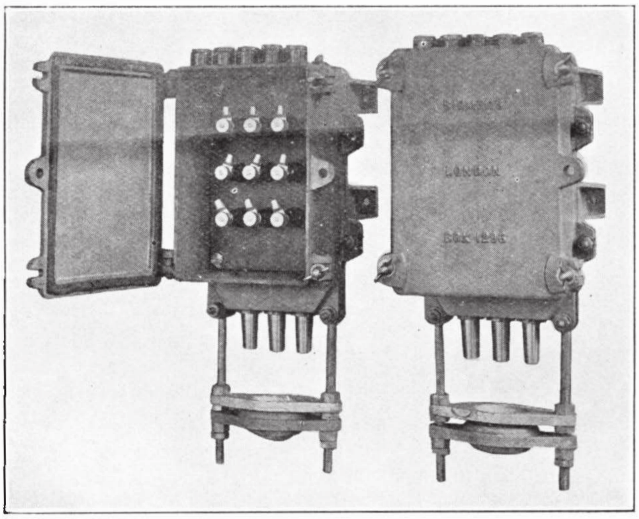


FIG. 3.—SPECIAL TERMINAL BOX.

Mr. J. Churchman, a Chief Inspector with a wide knowledge of underground work in the London Engineering District, was sent out in charge of the work and he had with him two experienced plumber - jointers in Messrs. Wheatley and Lilburn, also of the London District. A local gang of 50 was engaged for the unskilled work. The foreman or charge-hand engaged at Fayal understood both English and Portuguese and acted as interpreter, and he also succeeded in getting the best results out of the men. At the outset there was considerable difficulty experienced in securing permission to land the stores and tools at Fayal without paying exorbitant import taxes and municipal dues; the original claim was made that 120 per cent. of the value of all stores and tools should be paid to the Portugese authorities. Through the help of His Majesty's Ambassador at Lisbon it was finally agreed that the government and municipal taxes would be waived.

According to a law in operation at the Azores, it is laid down that if a workman is killed whilst at work, the employer is required to maintain the widow for life and also the children until they are self-supporting. If the workman is permanently injured, a large proportion of his wages is payable for life to his wife. In view of these legal obligations, combined with the facts that inexperienced labourers were being employed, that blasting work had to be done, also that heavy cable drums had to be transported on hilly roads rising 1 in 4, local arrangements were made to insure the workmen with a Portugese Insurance Company and the responsibilities for life pensions, etc., transferred to other shoulders. The only accident had to do, not with the workman, but with a cow which fell into the trench! The cow injured itself so severely that it had to be destroyed and the owner claimed damages. Although the trench was roped off and the cow was a trespasser, it was agreed with the Vice-Consul to pay a small sum to the native owner rather than to dispute the claim in the courts and probably waste time.

A demand was made at the outset by the night watchman engaged on the work that firearms should be issued to them because of the lonely nature of the roads at night time and possible visits of thieves. The application was considered, but the probable consequences from the use of revolvers far outweighed those from loss of tools, and the request was not granted. It is fair to say that there were no losses of tools to report.

A "cable drum carrier" was made in England and taken out for the handling of the drums of cable. This device, which consists of a pair of wheels and a special axle, enabled the drums to be lifted from the ground, taken to the site

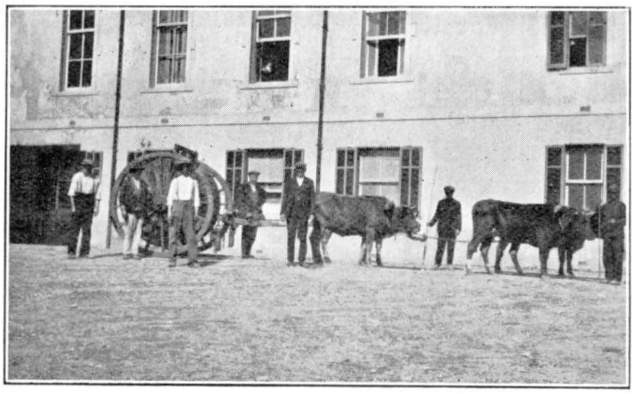


FIG. 4.—CABLE DRUM CARRIER.

and the drum revolved for the delivery of the cable at the trench. Bullock teams were used for transport purposes. Fig. 4 shows the cable carrier and its team of four bullocks ready to start work.

"Skids" had been provided with the cable carrier for use as brakes on hilly roads, but the municipal authorities declined to allow the skids to be used because of the loose nature of the roadway surface. The local custom is to use bullocks as brakes and this method was adopted in transporting heavy drums of cable down hill. Ropes were extended from the rear of the cable carrier and fixed round the necks of two bullocks who took the strain whilst moving slowly forward. The animals seemed to understand what they were required to do, and as a result, loads weighing nearly three tons were taken down some particularly steep hills. Fig. 5 shows this living brake in action.

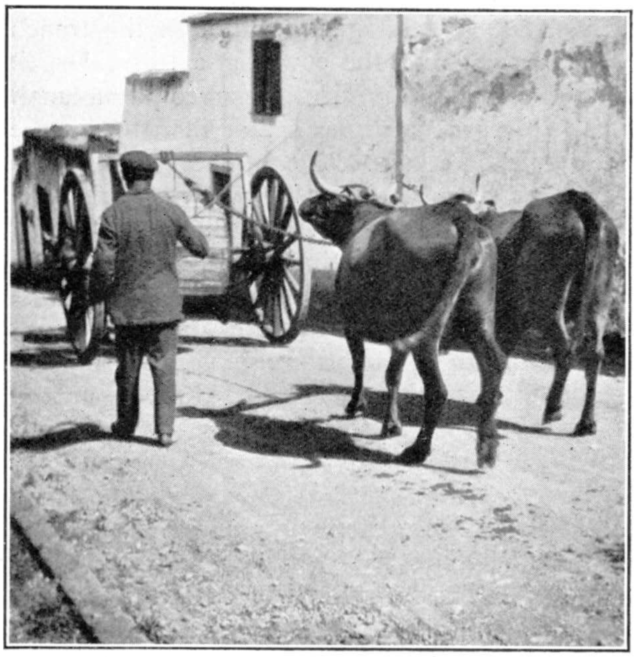


FIG. 5.—THE BULLOCK BRAKE.

Cable rollers were used in order to facilitate the running out of the cables in lengths of 220 yards. These rollers, which consist of a curved metal wheel free to revolve on a wooden base, were fixed at intervals alongside the trench; the cable paid out from the drum and placed on the rollers and finally the cable lifted into position in the trench. A sketch of the cable roller is shown in Fig. 6. A portion of the trench work in progress is shown in Fig. 7.

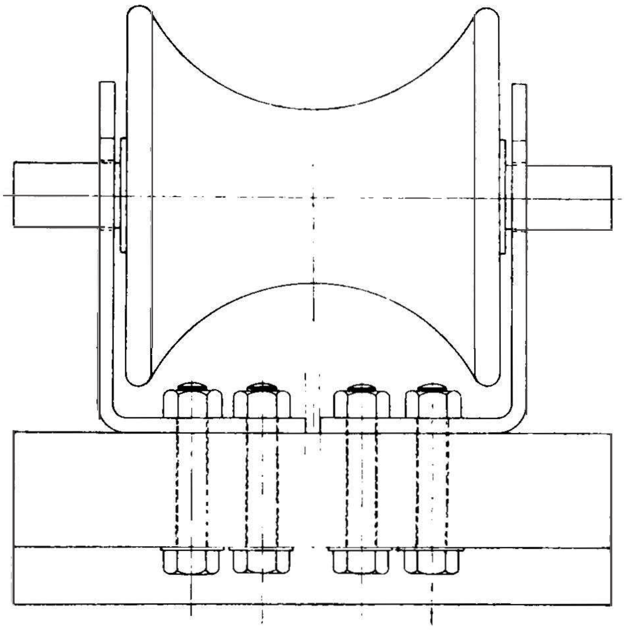


FIG. 6.—CABLE ROLLER.

Reference has already been made to the frequency of earthquakes at the Azores. Whilst the Post Office work was in progress shocks were experienced on two separate occasions. In the first instance a violent shaking of the ground occurred,—noises resembling rolling thunder attended by falling masonry and the screams of women and children. Later in the same day another disturbance occurred which resembled the knocking of a heavy steam hammer underground and causing violent movement of the earth. Fortunately no serious damage was done by these visitations. Two views of damage caused by former earthquakes are shown in Figs. **8** and **9**. Fig. **8** shows a deep fissure in one of the streets at Fayal, and Fig. **9** indicates the serious damage caused to one of the churches.

The nature of the sub-soil on the trench route varied from soft sand, loose stones, pumice stone, to hard rock. The latter was really hard and crumpled up the points of steel wedges without making any impression on the rock, and blasting had to be done. Some 70 yards of rock was treated in this way, often in roads with houses on either side which had already been cracked and dilapidated through recent earthquakes. In one instance, a house was occupied by the military authorities in which gun-powder was stored. The trench had to be cut within six feet of the wall of the building which was already very much cracked. Gummed paper was placed across the cracks in this instance before the blasting started and this paper was found to be intact after the explosion, otherwise it was feared that a claim for extensive repairs might have been made against the Department !

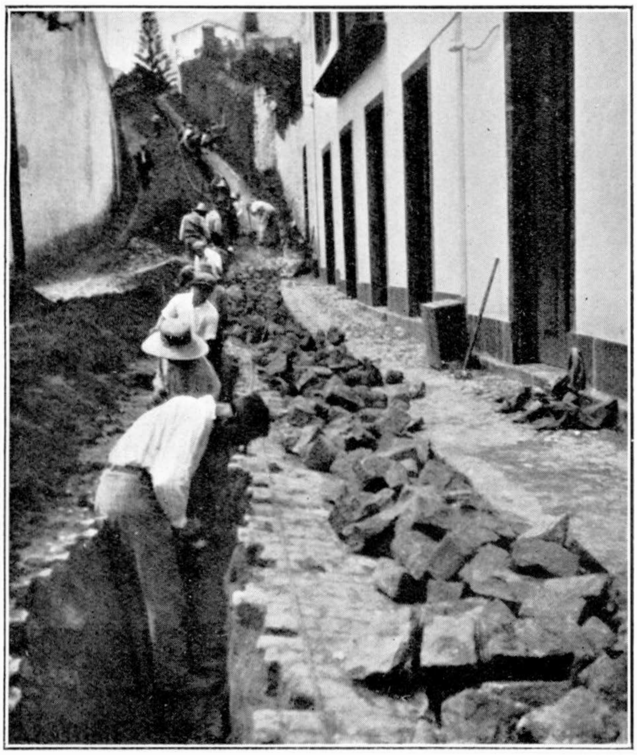


FIG. **7**.—TRENCH WORK AT FAYAL.

The reinstatement of roads after trenching caused some anxiety, as according to the municipal laws in operation at Fayal, the whole width of the road is required to be remade after a trench has been cut. After a discussion with the Civil Governor on this subject, it was agreed that, where the road was good and the trench carefully reinstated, so that the camber of the road was maintained, he would not insist on the application of the letter of the law. The authorities were satisfied with this arrangement in connection with the reinstatement of some 1,300 yards of trench, but in a length of ¾ mile, the reinstatement had to be effected to the whole width of the roadway, ranging from 15 feet to 20 feet. This involved digging over the entire surface and placing thereon two to three inches of " Saibro," a fine red volcanic sand which had to be dug and sifted at a quarry nearly 2½ miles away and carted by bullock wagons to the points required. On one occasion the Department had as many as 17 wagons and 34 bullocks employed on this work.

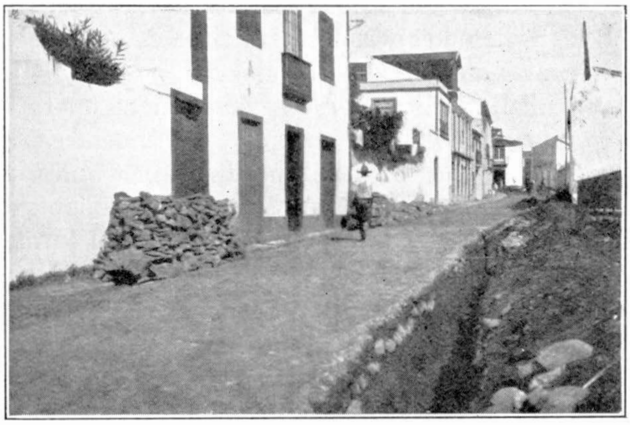


FIG. **8**.—FISSURE CAUSED BY EARTHQUAKE.

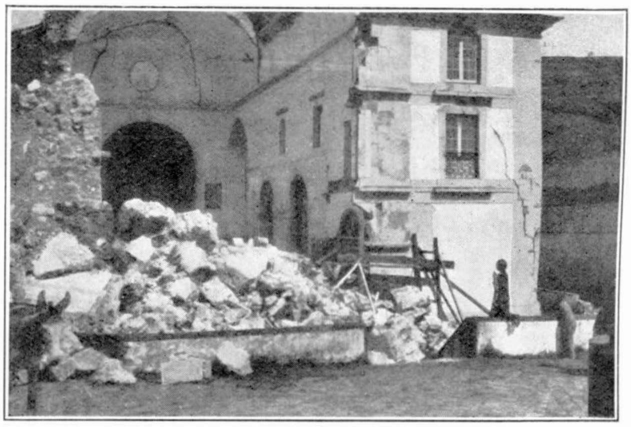


FIG. **9**.—DAMAGE DONE TO CHURCH BY EARTHQUAKE.

An antiquated roller, some 7 feet long and 4 feet in diameter was hired for the reinstatement work. This looked like an old marine boiler provided with a door at each end so that the roller could be filled with earth. A centre pole was fitted and the machine drawn by bullocks. In some portions of the road, with gradients of 1 in 4, eight bullocks were required and formed quite a procession, as a goader or driver was required for each pair of bullocks; in addition, men followed up with shovels in order to keep the surface of the roller clean. Fig. **10** shows the roller, complete with bullocks and drivers.

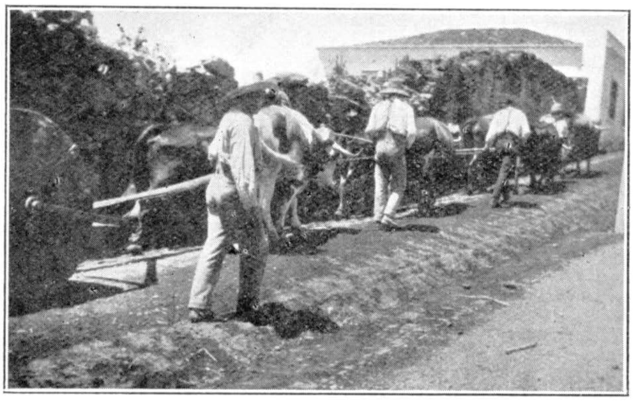


FIG. **10**.—REINSTATEMENT WORK IN PROGRESS.

Generally speaking the native labourers were found to be hard working, eager, and good time keepers. As an example of this, the night watchmen, whose duty did not commence until 5 p.m., were in the habit of assisting in the digging and the performance of odd jobs for two hours before they were due to commence work on their night watching operations. In passing, it should be mentioned that the pay of the labourers engaged on the work was based on rates paid for similar work by the cable companies and was in advance of the normal labourer's wage at Fayal; there was much competition for employment. It is interesting in this connection to note that the casual labourers at Fayal sometimes have a stroke of luck when a whale is sighted off the coast. The appearance of the whale is reported by the firing of a gun from one of the hills and when this signal is heard every man throws down his tools and rushes off to chase and kill the whale. This operation usually takes about three days to accomplish and, as a result, local labour is at a standstill until the great adventure is over. Fortunately, no whales were signalled during the progress of the Department's operations and the work was carried through without interruption from start to finish.

The writer desires to express his thanks to Mr. Churchman for much assistance in the preparation of this article and, in particular, for the photographs of the operations at Fayal.

A. O. G.

THE MEASUREMENT OF INDUCTANCE AND EFFECTIVE RESISTANCE OF LOADING COILS.

L. E. Ryall, B.Sc., Eng.

BOTH the inductance and the effective resistance of the loading coils in underground lines affect the characteristics of the line considerably, and hence the accurate measurement of these quantities is important.

As the attenuation of a loaded line is approximately proportional to the resistance of the line, (for the same type of loading) the effective resistance of the loading coils inserted in the line must be made as small as possible. If we assume that 40 lb. conductors, with 177 mH. loading at 1.125 miles spacing, have unit attenuation if the loading coils have no resistance, in practice, with the loading units at present in use, attenuations of 1.25 units at 1000 p.s. and 1.40 units at 2000 p.s. are observed. The effective resistance of these units at various frequencies is shown in Fig. **1**.

The accurate measurement of the inductance of loading coils presents little difficulty and can be performed satisfactorily by a number of the a.c. bridge methods, provided that the Wagner earthing device for maintaining the telephone receiver at earth potential be used.

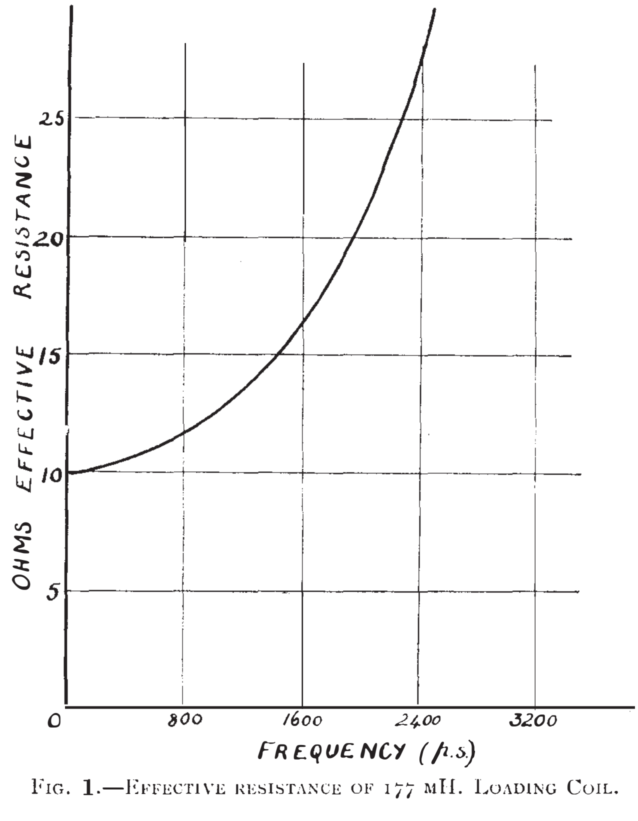


Fig. **1**.—Effective resistance of 177 mH. Loading Coil.

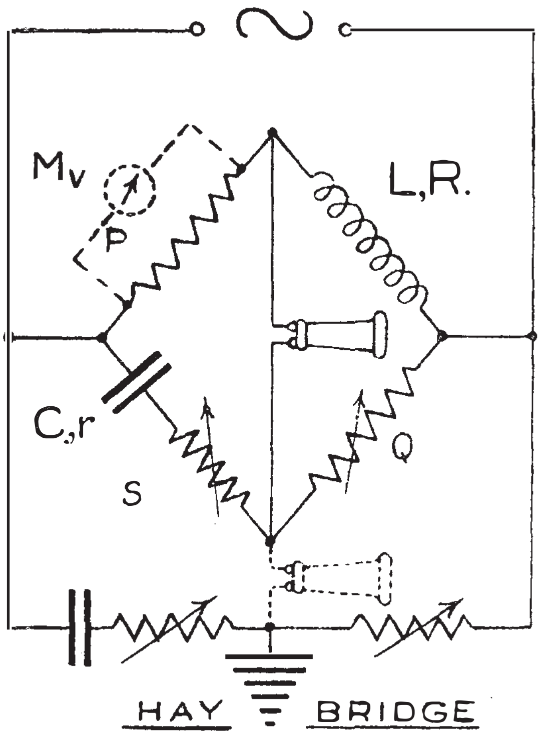


Fig. **2**.

The effective resistance of the modern dust core loading coil is very small, and the angle of the impedance is nearly 90°. Hence, unless the resistances, condensers, etc., comprising the bridge are pure, the value of the effective resistance obtained may be very different from the true value.

The Hay bridge, Fig. **2**, is very suitable for measuring inductances with good angles. The usual formulæ for the inductance, L (henries), and effective resistance, R (ohms), if the bridge resistances and condensers are pure, are as follows :—

$$L = \frac{PQC}{1+\omega^2C^2S^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$R = \omega^2 LCS \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$= \frac{\omega^2C^2PQS}{1+\omega^2C^2S^2}$$

These formulæ are correct only :—

(*a*) If the rheostats used in the bridge are non-reactive, and

(*b*) If the condenser has no loss.

The condition (*a*) can be met sufficiently if the highest grade rheostats are used. It is important, however, that these rheostats should have a maximum value not greater than about 1100 ohms, as the addition of a " thousands " dial, even if not in use, is liable to introduce slight capacity errors in the instrument. These capacity errors reduce the value of the bridge resistance S, and this reduction is independent of the frequency. As the effective resistance to be measured is a function of ω^2S, the error introduced in the effective resistance is proportional to $(\text{frequency})^2$. This error, however, is negligible up to 3000 p.s. if the highest grade rheostats are used under the conditions specified above.

Condition (*b*) can only be satisfied by using a condenser with air dielectric. The best mica condensers have a power factor of between 0.0002 and 0.0003, which gives an error of between 4% and 6% in the resistance measurement of a dust core loading coil, at a frequency of about 1600 p.s. This condenser loss can be represented by a resistance r, placed in series with the pure capacity of the condenser, so that the power factor of the combination is the same as that of the mica condenser under consideration. This equivalent resistance r of the mica condenser can be determined by making measurements of a coil, using the series resonance bridge in conjunction with the Hay bridge.

THE SERIES RESONANCE BRIDGE.

The circuit diagram is shown in Fig. **3**. In general the resistances N, P and Q are each 100 ohms.

If the resistances N, P and Q are assumed to be non-reactive, the values of L and R, for equal values of P and Q, are given by the equations

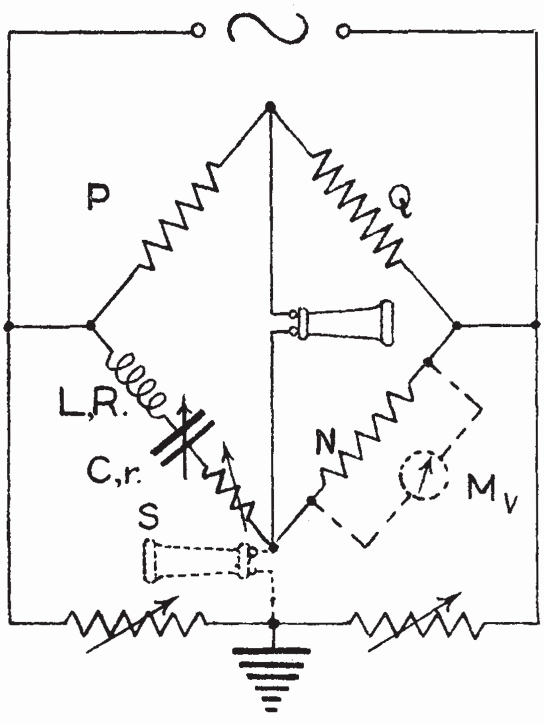
$$L = \frac{1}{\omega^2 C}$$

$$\text{and} \quad R = N - S - r.$$

where r is the equivalent resistance of the condenser of capacity C.

It is seen that the true resistance, determined by this bridge, is *less* than the apparent resistance, if the resistance component r of the condenser, C, is neglected.

If now, the value of R is determined by the Hay bridge, using the same capacity C of the condenser, and balancing the bridge by varying P, Q and S, then



SERIES RESONANCE BRIDGE.

FIG. **3**.

$$R = \omega^2 CL(S+r)$$

$$\textit{i.e.,} \quad R = S + r$$

$$\text{since} \quad \omega^2 CL = 1.$$

Thus the true resistance is *greater* than the apparent resistance if r is neglected. Hence, if the mean of the two values of R, as found by the series resonance bridge and the Hay bridge, be taken, the error due to the resistance of the condenser is eliminated.

Use of Air Condenser in Hay Bridge.

To facilitate the measurement of loading coils, a large air condenser, of capacity 0.04 microfarads was made up. It consisted of two sets of brass plates, (50 plates per set), each plate being 12 inches square and 0.045 inches thick. The clearance between adjacent plates was approximately 0.070 inches. Each set of plates was securely mounted on four stout brass pillars and rigidly clamped to, but insulated from, a cast aluminium base. Each set of plates was turned through an angle of 45° with respect to the other set. The condenser was completely screened and mounted in a cubical case, its overall dimensions being 21 inches.

The resistance of this condenser, as determined by the two bridge methods described above, was found to be less than 0.1 ohms. Hence the values of the resistance and the inductance of loading coils can be found accurately using only the Hay bridge, since the large size condenser needs comparatively small resistances for the bridge arms, P and Q, and thereby rheostat errors are reduced to a minimum.

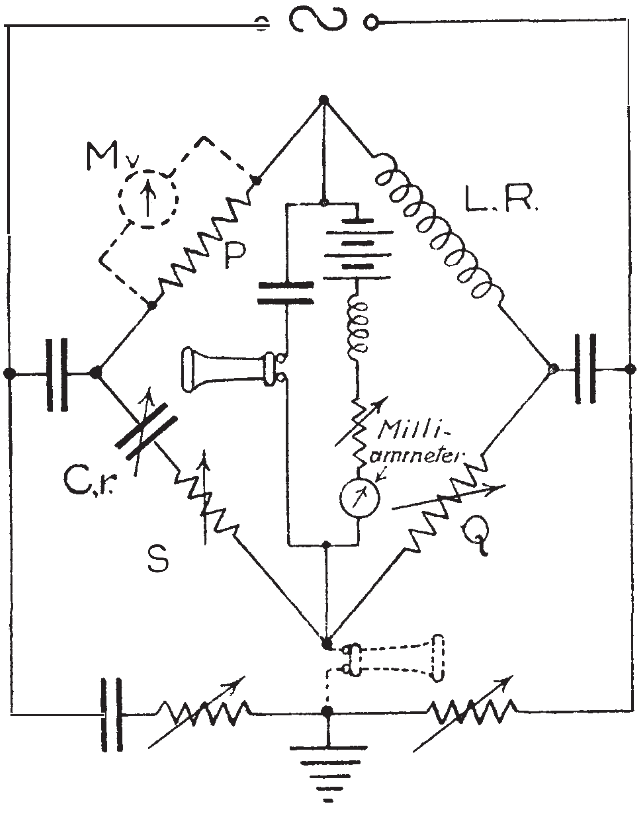


Fig. **4**.—Measurement of Inductance with D.C. flowing through Coil.

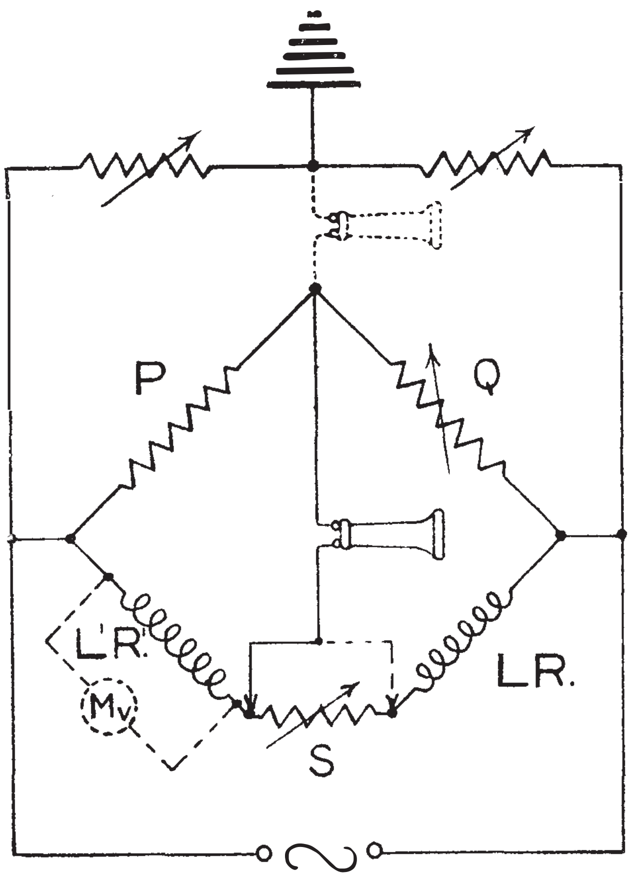


Fig. **5**.—Slide Wire Comparison Method.

Measurement of Inductance with D.C. flowing through the Coil under Test.

The modifications necessary in the Hay bridge to enable the inductance of a coil with D.C. flowing through it to be measured are shown in Fig. **4**. A low resistance choke is inserted in the battery leads to prevent the telephone receiver being short-circuited.

The value of the testing current (a.c.) is most satisfactorily measured by reading the voltage across the resistance P with a Moullin type thermionic voltmeter M. The voltmeter should be removed before final adjustment of the bridge is made.

Slide Wire Comparison Method for the Measurement of Inductance and Resistance.

For rapid testing of large numbers of coils (*e.g.*, acceptance tests), a slide wire comparison test can be made.

The circuit diagram is shown in Fig. **5**.

The coil L,R, to be measured is compared with a standard coil L′R′.

The values of L and R are given by the formulæ—

$$L = L' \frac{Q}{P}$$

$$R = (R' + S) \frac{Q}{P}$$

If $R < R' \frac{Q}{P}$, connection to resistance S from the telephone should be made as shown by the dotted lines, and then,

$$R = R' \frac{Q}{P} - S$$

If the standard coil has approximately the same angle as the coil under test, the resistance S will be very small or zero, and errors due to the reactive component of this resistance can be neglected.

Further, provided the inductance of the standard coil is of the same order as the test coil, the resistance P will be of the same order as resistance Q, and, if these resistances are of the same type (and practically non-reactive), the angles of these resistances will be the same, and no error will be introduced in the value obtained for the inductance L and the effective resistance R of the coil under test.

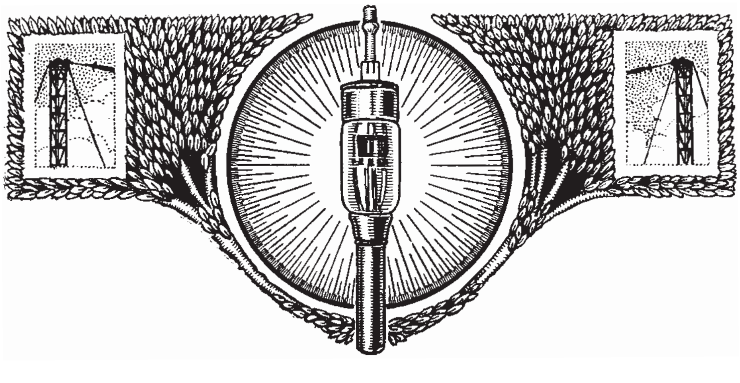
A good quality loading coil forms a satisfactory standard coil, and should be calibrated, as described previously, with specified a.c. test currents. The a.c. test current can be ascertained by measuring the voltage across the standard coil with a Moullin type thermionic voltmeter, which should be disconnected before making final bridge adjustments.

It is important that no direct current should be passed through the standard coil, as the inductance would be altered by so doing.

Summarising these results, it is seen that for accurate measurement, by means of the Hay bridge, of the effective resistance of loading coils, the bridge rheostats must be as non-reactive as possible, and the bridge condenser must be an air condenser of large capacity, or else its resistance must be determined. The Hay bridge is then satisfactory for loading coil measurements, using frequencies up to 3000 p.s. It is estimated that the inductance can be measured with an error of less than ±0.5% and the resistance can be measured with an error of less than ±2%.

For rapid routine testing a slide wire comparison method may be used. A standard loading coil, of which the inductance and effective resistance are known, is then required.

This article gives details of measurement by means of capacity bridges only, as previous work on bridges using inductance had indicated that accurate results could not be obtained without specially made (and very expensive) inductance coils, in the use of which elaborate precautions are necessary to avoid errors due to stray magnetic fields and capacity effects.



NOTES & COMMENTS

PROFESSIONAL CIVIL SERVANTS.—The dinner of the Institution of Professional Civil Servants was held at the Connaught Rooms on Thursday, 29th November. Sir Samuel Hoare, Secretary of State for Air, was the principal guest and proposed the toast of the Institution. Sir Richard Redmayne, President of the Institution, replied.

Mr. F. A. A. Menzler, Chairman of the Council of the Institution, proposed " The Guests," and Sir Russell Scott, Controller of Establishments at the Treasury and Chairman of the National Whitley Council, and Professor Julian Huxley replied.

There were 330 present, and amongst the guests were:—Sir Evelyn P. Murray, K.C.B., Secretary, Post Office; Sir Brodie H. Henderson, K.C.M.G., C.B., President, Institution of Civil Engineers; Lt.-Col. K. Edgecumbe, R.E.(T.), President, Institution of Electrical Engineers; Professor Julian S. Huxley, President, Association of Scientific Workers; and Mr. C. B. Fisher, C.B.E., President, Surveyors' Institution.

The Civil Service Arts Magazine.—We are pleased to note that the Arts movement in the Civil Service will soon have its own Magazine. An influential Editorial Committee, representing the various arts, has been formed to produce an illustrated Quarterly, " The Civil Service Arts Magazine," price sixpence, the first number of which will appear early in the New Year. The Committee is as follows:—Sir Cecil Harcourt Smith, C.V.O., L.L.D.; Prof. W. Rothenstein; Dr. Arthur Somervell, Mus. Doc.; Mr. N. Curtis-Bennett, C.V.O.; Dr. G. F. Herbert Smith, D.Sc.; Mr. C. J. G. Tate, O.B.E.; Mr. F. M. Chapman; and the Editor is Mr. S. McKechnie.

" The Civil Service Arts Magazine " will publish announcements and reports supplied by the various Societies, and a great deal of space will be devoted to lengthy and authoritative criticisms of Dramatic Performances, Art and Photographic Exhibitions, Concerts, etc., with illustrations. Articles on the different arts and book reviews will be a prominent feature, and for these the Magazine is assured of the services of many notable writers. The art paper and high-class printing will make the Magazine a record of their activities and achievements which members of Societies will be proud to treasure. The Magazine, of course, will also appeal to the general reader with an interest in the various arts.

Communications from those willing to act as Agents or assist in any way should kindly be sent to the Editor, " The Civil Service Arts Magazine," Room 208, Treasury Chambers, London, S.W.1.

Mr. H. M. Pease has relinquished the position of Managing Director of Standard Telephones and Cables, Limited, due to the pressure of work occasioned by his position as Vice-President and General Manager in Europe of the International Standard Electric Corporation.

Mr. Frank Gill has been appointed Chairman of the Board and Mr. E. S. Byng Managing Director of Standard Telephones and Cables, Limited.

Mr. Reginald Alexander Dalzell, formerly Director of Telegraphs and Telephones, died at Dulwich Village on Tuesday, 27th November, at the age of 63. The following notice is taken from *The Times* of the 28th November:—

"Mr. Dalzell was the son of the late Mr. Nicholas A. Dalzell, Conservator of Woods and Forests, and was born at Poona in 1865. He was educated at Dulwich College, and in 1881 entered on his long connexion with the telephone service, first with the Globe Company, then with the United Company, and afterwards with the National Telephones. When the National Company was taken over by the State in 1912, Mr. Dalzell, who was then Provincial Superintendent for the West of England, was transferred to the Post Office, and in 1916 became head of the Traffic Section. In 1922 he was promoted to be Director of Telegraphs and Telephones, and Mr. Kellaway, who was then Postmaster-General, in announcing the new appointment, described Mr. Dalzell as one of the ablest men on the telephone side. One of the most important developments during his tenure of office was the opening of the Transatlantic telephone service. By his friends at the Post Office his death will be felt as a real personal loss, for they had learnt to know him not only as a very competent departmental chief, but also as a very lovable colleague. He retired from the service only in July of last year. Mr. Dalzell leaves a widow and one daughter."

The Telephone Development Association has taken a large space at the Schoolboys' Own Exhibition in the New Horticultural Hall, Westminster, from December 29th till the 5th January, for educational work in connection with the use of the telephone. An actual working board of automatic apparatus is being shown, as the Association is of the opinion that that type of apparatus will be universal when the youngsters are old enough to have an office or house of their own. Side by side with this exhibit, are shown early models of telephone parts and apparatus, Graham Bell's first telephone, etc., lent and arranged by the South Kensington Science Museum, to demonstrate the enormous advances made in telephone engineering during the last fifty years.

The Association has been pressing upon the Government the desirability of increasing capital expenditure on telephone works, which, it is argued, can be made revenue earning without undue loss of time by an energetic publicity campaign. Figures are quoted from the Commercial Accounts of the Post Office, showing that during the past five years the net surplus from the telephone service, after paying Interest on Capital, Administrative and operating expenses, maintenance, depreciation, pensions, etc., has amounted to £3,833,137, which amount, of course, has reverted to the Treasury. There were lean years earlier, however, before the rates were raised, and Sir Henry Bunbury has pointed out that the capital cost per station is continually rising. A publicity campaign to induce subscribers to use their telephones oftener would also be of value.

The High Commissioner for Canada in London communicates the following paragraphs prepared by the Natural Resources Intelligence Branch of the Department of the Interior at Ottawa:—

Canadian Trans-Continental Telephone Line. Western Link Completed.

On November 6th last, telephone conversations were exchanged between Edmonton, Alberta, and Victoria, B.C., in order to mark the completion of the western link in the "All-Canadian" trans-continental telephone line.

From Edmonton Dr. William Egbert, Lieutenant-Governor of Alberta, conversed with R. R. Bruce, Lieutenant-Governor of British Columbia at Victoria. The Hon. F. S. Tolmie, Premier of British Columbia, was switched through from Victoria to Dr. Egbert at Edmonton and the Hon. J. E. Brownlee, Premier of Alberta, who was in Vancouver, got in touch with the Hon. V. W. Smith, Minister of Railways and Telephones, at Edmonton. The Mayor of Vancouver also conversed with the Mayors of Calgary and Edmonton. The line was in perfect working order and the transmission was so good that all the conversations were heard as easily and distinctly as if between adjoining rooms, instead of over long ranges of mountains in two Provinces.

The completion of the new line not only enables Calgary, Edmonton, Vancouver, Victoria and other points in Alberta and British Columbia to converse with each other and with points in central Canada over all-Canadian wires, but with the last link between Quebec and New Brunswick nearing completion, forms an important link in a coast to coast service which is assured in the near future, with no foreign point touched.

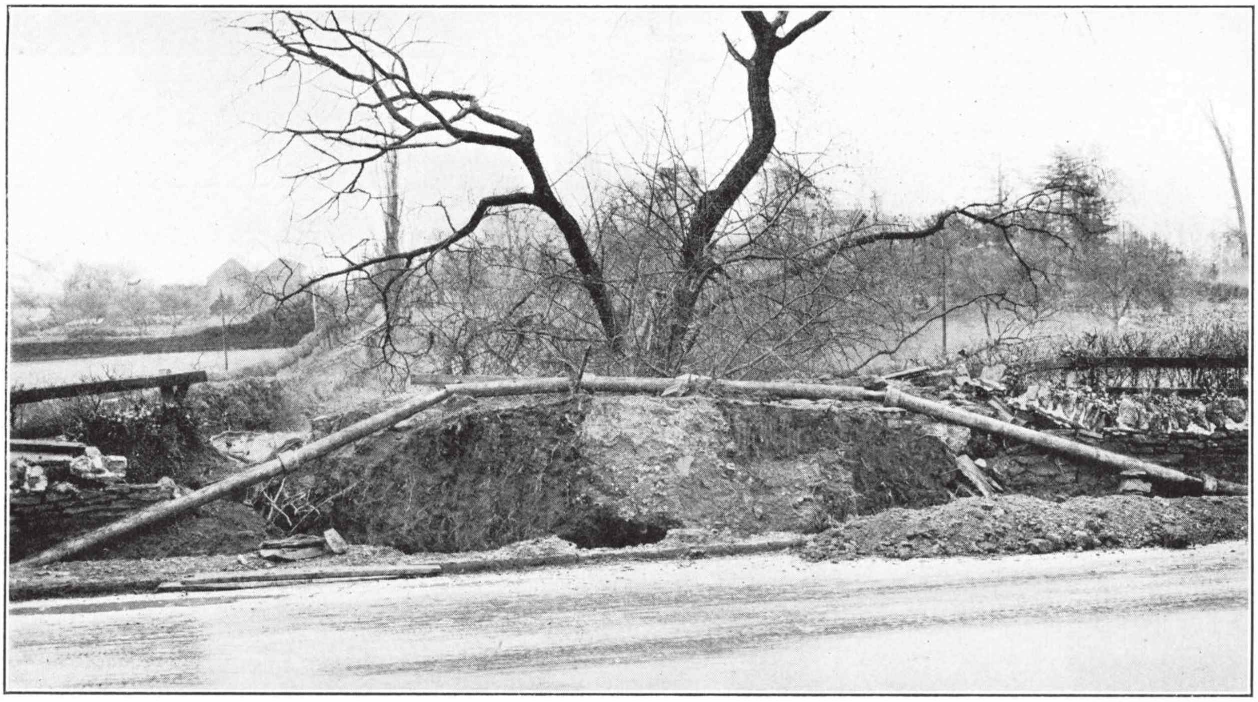
Radio Telephone Service Proposed for British Columbia Coast.

The British Columbia Telephone Company contemplates the installation of a radio telephone service to outlying points along the Pacific coast of Canada where conditions render the ordinary ground lines prohibitive owing to their cost.

A Unique Occurrence.—The severe gale which swept over England on the 16th of November uprooted many trees. At Brislington, a suburb of Bristol, the Western underground pipe and cable in the footway were lifted out of the ground by the roots of a large elm tree which was blown down. The tree, which fell into the adjoining field, stood immediately on the field side of a low wall which forms the boundary of the footpath.

The cable is a composite one, being made up of the following conductors:—28 pr./100 Q.P. +6 pr./100 Tw. + 15 pr./150 Tw. + 22/200 S.S. +42/70 S.S. It is approximately 3½″ in diameter, and is carried in a 4″ C.I. pipe. The pipe was laid over 20 years ago, at a depth of 14″, and the roots of the elm tree had grown around it.

The position into which the pipe and cable were raised on the roots of the tree is shown in the photograph. The pipe and cable were lifted from the ground for a distance of 10 yards, the maximum height above the footway level being 4 ft. The maximum horizontal displacement was 4 ft. 6 inches. In order to avoid the increase in the strain on the cable which appeared likely to result from the settling down of the fallen tree, the trunk of the tree was sawn off near the roots. After roots and soil had been removed sufficiently to permit of the work being carried out, the pipe and cable were lowered to their former position so far as this could be done. The cable slack which resulted from the strain could be only partially taken up in the trench.



Western Underground Pipe and Cable lifted by roots of falling elm near Bristol.

A coupling existed at a distance of 23 yards from the fallen tree on the Bristol side, and it was desired to examine the conditions at this joint without delay. Another large elm tree stood in the roadside bank at this point, however, and cracks in the footway, due to the strain to which the tree had been subjected by the gale, showed that the ground could not safely be disturbed until the tree had been felled.

When the cable was examined at this coupling point it was found that it had been drawn a distance of 4″, and that the plumber's wipe was jammed against the shoulder of the coupling. On opening up the joint it was apparent that the displacement of conductors and sheathing, respectively, had been unequal, and that the conductors had drawn through the sheathing. The nearest joint on the Bath side was 93 yards distant from the uprooted section of cable, and it was found at that point that the displacement of the cable was 2″.

It is remarkable that notwithstanding the extraordinary strain to which the cable was subjected no faults resulted. Five pipes were badly fractured, and the cable sheathing was heavily indented in several places and otherwise damaged. It was decided to replace the damaged cable over a length of 40 yards and this work has been carried out.

A. RATTUE.

HEADQUARTER'S NOTES.

EXCHANGE DEVELOPMENTS.

The following works have been completed :—

Exchange.	Type.	No. of Lines.
Bermondsey	New Auto.	2600
Monument	,,	10000
St. Marychurch	,,	317
Brighton	Auto Extn.	—
Cheltenham	,,	535
Hove	,,	—
Leeds	,,	—
Portslade	,,	90
Rottingdean	,,	80
Southwick	,,	570
Bishops Stortford	New Manual	460
Byfleet	,,	700
Chigwell	,,	520
Fleet	,,	520
Harpenden	,,	700
Horsham	,,	720
Norbury Relief	,,	1000
Rainham (Essex)	,,	740
Tudor Relief	,,	3500
Bristol	Manual Extn.	1700
Cambridge (Advance)	,,	1480
Mansfield	,,	460
Port Talbot	,,	180
Purley	,,	1020
Putney	,,	1040
Smethwick	,,	580
Streatham	,,	660
Sydenham	,,	400
Willesden	,,	1700
Broome and Foster	P.A.B.X.	30
Dudley Guardians	,,	30
Fleetwood Co-op. Society ...	,,	20
Gonville & Caius College ...	,,	20
Jarrow & Hebburn Co-op. ...	,,	30
Manchester Corporation ...	,,	300
May & Co. T.	,,	20
Morris Garages, Ltd.	,,	20
Pearson Dorman Long ...	,,	40
Ratcliffe & Ratcliffe	,,	20
Reading Co-op. Society ...	,,	20
Trade Union Congress ...	,,	100
Walter Martin, Ltd.	,,	20
Wimbledon Motors, Ltd. ...	,,	30
Illustrated London News ...	P.A.B.X. Ex.	50
Jeager Co., Ltd.	,,	—
Outram & Co.	,,	20
Royal Arsenal Co-op.	P.A.B.X. Ex.	30
Synthetic Ammonia, Ltd. ...	,,	200
Walsall & W. Bromwich Union	,,	20
West Riding C. Council ...	,,	40
Wiggins & Co.	,,	30

Orders have been placed for the following works :—

Exchange.	Type.	No. of Lines.
Blackfriars (Manchester) ...	New Auto	9700
Livingstone	,,	3000
Manchester	Auto Manual	200 (Posns.)
Cwmbran	Auto Extn.	127
Exeter	,,	760
Harrogate	,,	1700
Newport (Mon.)	,,	400
Redhill	New Manual	1264
Skegness	,,	620
Bournemouth	Manual Ext.	680
Brixton	,,	800
Canterbury	,,	700
Derby	,,	1060
Greenwich	,,	1080
Norwich	,,	380
Broome & Foster	New P.A.B.X.	30
Davis Theatre, Ltd.	,,	30
Edwards Ringer & Bigg, Ltd.	,,	30
J. Garner & Sons	,,	30
Gonville & Caius College ...	,,	20
Jarrow & Hebburn Co-op. ...	,,	30
Manchester Corporation ...	,,	300
Preston Corporation	,,	20
Southern Oil Co.	,,	20
Universal Grinding Wheel Co.	,,	30
Wimbledon Motor Works ...	,,	30
Dunlop Rubber Co.	P.A.B.X. Ex.	10
Illustrated London News ...	,,	50
Jaeger Co., Ltd.	,,	—
Lloyds Packing Warehouses...	,,	30
London Express Newspaper ...	,,	40
Royal Arsenal Co-op.	,,	30
Walsall & W. Bromwich Union	,,	20
West Riding C. Council ...	,,	40
Wiggins & Co.	,,	30

LIEUT-COL. A. S. ANGWIN, B.Sc., D.S.O., M.C., T.D.

Lieut.-Col. A. S. Angwin, D.S.O., M.C., T.D.

Lieut.-Col. A. S. Angwin, who succeeded Lieut.-Col. A. G. Lee as Staff Engineer in charge of the Radio Section at headquarters in June, 1928, graduated B.Sc. (Engineering), at London University from East London College after winning a Whitworth Exhibition scholarship in 1902. He was apprenticed to Messrs. Yarrow and Co., the well-known engineers and shipbuilders, and passed through their shops and drawing office.

He entered the P.O. service as Second Class Engineer by open competition in 1906, and after probationary training in Hornsey Section he was appointed to Glasgow Construction Section. From 1909, he acted as sectional engineer in charge of underground and exchange construction for new Glasgow exchanges and transfer of N.T. Coy.'s plant.

Always an enthusiast in military matters, he raised the Lowland Division Telegraph Coy., on the formation of the Territorial Force and was gazetted Captain in command of the Company. This company was comprised, officers and men, almost entirely of Glasgow P.O. officials, telegraphists, linemen, etc. The unit was mobilised in 1914, and formed into the 52nd Divisional Signal Company with Captain Angwin, promoted Major, as Officer in Command. He served through the war with the unit in Gallipoli, Egypt, Palestine and France. Major Angwin was mentioned in despatches five times, and was awarded the M.C., and the D.S.O. After the war he commanded the 44th (Home Counties) Divisional Signal Coy. until 1927, when he was awarded the T.D. (20 years' service). He is now serving as Deputy Chief Signal Officer, Eastern Command.

Col. Angwin returned to Glasgow after the war for three months, but was transferred to the Engineer-in-Chief Office Wireless Section in connection with the work at Leafield and Cairo Wireless Stations, which were to form part of the Imperial Chain. He was appointed Executive Engineer in April, 1920, and twice renewed his acquaintance with Egypt over the building and operation of the Cairo Station. He was largely responsible for the construction of the Rugby Masts and Aerial Systems and in conjunction with Mr. Walmsley he was awarded the Telford Premium by the Institution of Civil Engineers for a paper on that subject read before the Institution.

Col. Angwin was promoted Assistant Staff Engineer in March, 1925. He was closely associated with the construction of the Radio Beam Stations, supervising the contracts with the Marconi Coy., checking the work in progress and carrying out experimental and research investigations. Along with Messrs. Shaughnessy and Lee he had been engaged in the development of Transatlantic Telephony in collaboration with the A.T. and T. Company, and last year he paid a visit to the States in connection with the provision of additional channels to be operated on Short Waves to carry the growing traffic.

He is an Associate Member of the Institution of Civil Engineers, and a Member of the I.E.E.

LONDON DISTRICT NOTES.

Telephones.—The following figures shew the changes in the number of exchange lines, extensions, and stations during the three months ending 30th September, 1928, and the total at the same date: —

	Increase.	Total.
Exchanges lines ...	5,777	347,598
Extensions ...	4,515	292,170
Stations	9,836	583,567

External Plant.—During the same period the changes shewn below have occurred in mileage:

Telegraphs.—A nett decrease in open wire of 20 miles and a nett increase of 325 miles in underground.

Telephones, Exchange.—A nett decrease in open wire (including aerial cable) of 2 miles and a nett increase of 64,591 miles in underground.

Telephone, Trunks.—A nett increase in open wire of 7 miles and a nett increase of 909 miles in underground.

Pole Line.—A nett increase of 19 miles, the total to date being 5,887 miles.

Pipe Line.—A nett increase of 281 miles, the total to date being 10,041 miles.

The total single wire mileages at the end of the period under review were:—

Telegraphs	25,780
Telephones—Exchange ...	2,368,307
,, Trunk	74,188
Spares	99,542

TELEPHONE EXCHANGE PROGRESS.

The following information will give an indication of the progress that is being made in providing new Telephone Exchanges in the London Area.

The Monument Automatic Exchange, with Mansion House Hypothetical working thereon, was opened for traffic on the 3rd November. The exchange is situated in the present Royal Exchange building, and is equipped for 9450 lines.

The following Manual Exchanges have been opened recently:—

Chigwell, No. 1 C.B., type equipped with 520 lines, opened October 18th.

Rainham, No. 1 C.B., type equipped with 740 lines, opened October 28th.

Tudor, No. 1 C.B., type equipped with 5,000 lines, opened November 1st.

Molesey and Sutton New Manual Exchanges are rapidly nearing completion and will be opened early in January.

The following New Exchange Buildings are being equipped:—

Auto Exchanges.		Manual Exchanges.	
Exchange.	No. of equipped lines.	Exchange.	No. of equipped lines.
Welbeck	8700	Pollards (Relief)	1900
Beckenham	3000	Valentine (Relief)	1500
Temple Bar	7700	Hornchurch	880
Reliance	2700		
Metropolitan	9500		
National	9500		
Western	7100		
Maida Vale	7500		
Archway	3100		
Edgware	1300		
Hendon	3100		
Flaxman	9900		
Fulham	7500		

New Exchanges on which building construction work has been commenced.

Addiscombe.
Amherst (Hackney Area).
Emberbrook (Ditton Area).
Hillside.
Ilford.
Gulliver (Kentish Town).
Livingstone (Norwood).
Loughton.
Macaulay (Nine Elms)
Mitcham.
Pollards (Norbury).
Primrose Hill.
Prospect (Barnes).
Redhill.
Shepherds Bush.
Stanmore.
Terminus (King's Cross).
Upminster.

New Exchanges on which building construction is on the point of being started.

Ingrebourne (Harold Wood).
Leytonstone.
Romford.
Theydon Bois.
Whitehall.

In addition to the above cases, sites for 21 new exchanges have been secured, and searches for suitable sites are being made in 14 other cases.

POWER WORK.

Following the adaptation of the old Letter Office at Mt. Pleasant for Parcel work, 19 band conveyors have been installed to facilitate transport of parcels and bags between the sorting points, loading platforms, and the chutes leading to the P.O. Railway Station. The conveyors have bands varying from 30″ to 36″ wide, running at a speed of 200 feet per minute and capable of carrying total loads varing from 1,040 to 4,400 lbs.

The erection of a new 800 k.w. motor converter of the La Cour type in the Mt. Pleasant Sub-station is practically complete, and tests *in situ* will shortly be made. The set takes current at 6600 volts 3-phase 50 cycles on the A.C. side and delivers at 440 volts D.C.

TELEGRAPHS.

The Public Telegraph Office at the G.P.O. West has been removed from the rear to the front of the building in St. Martin's-le-Grand. This has involved the shifting of tubes, telephones, etc. The improved general appearance and accessibility of the Office should bring about a considerable increase of business.

The well-known "Centre" in the C.T.O. has now been surrendered by the builders, who have constructed a new floor, supported by a bridge across the southern half of this telegraph gallery. Three multiplex sets have already been restored and the opportunity is being taken to supersede the old metal-framed tables by wood tables of solid construction. It is hoped that by this means vibration will be practically eliminated. Collection of messages by band carriers is to follow.

Additional four-slip electrical perforators have been installed to displace a number of old style pneumatic punchers.

The number of Teleprinters continues to increase. These are chiefly of the 3-A type. The necessity for adapting the machines to alternating current working has arisen and instruments fitted with alternating motors are now being tried on a London circuit.

There has been an appreciable increase in the number of Teleprinters fitted in London for private wire renters.

PNEUMATIC TUBES.

It may not be generally known that the pneumatic power supplied for tubes which are provided for renters is measured in terms of time. Meters are fitted and governed by contact points which function when the valves are operated. A new type of meter is now under trial.

Many complaints have been received about the noise occasioned in instrument rooms by pneumatic tube working. India-rubber carriers are about to be extensively tried, on both large and small house-tubes. The experimental carriers have been found quieter in working and it is hoped that the noise will be materially reduced.

TELEPHONE KIOSKS.

There are now 1,119 Kiosks in the London area. The increase last quarter was over 20 per cent.

THE INSTITUTION OF P.O. ELECTRICAL ENGINEERS.

LONDON CENTRE.

THE meeting of the Centre on Tuesday, the 13th November, was favoured by the presence of Dr. T. A. Watson, who was on a visit to this country from the United States and who had kindly consented to give an address on "The Birth of the Telephone." The Engineer-in-Chief, president of the institution, presided and introduced Dr. Watson to the packed audience in a felicitous speech. The audience stood up *en masse* when Dr. Watson rose to speak and received him with loud and continued applause. At the close of his address, which was delivered in a charming manner with many bright personal touches, Dr. Watson was awarded a very cordial vote of thanks.

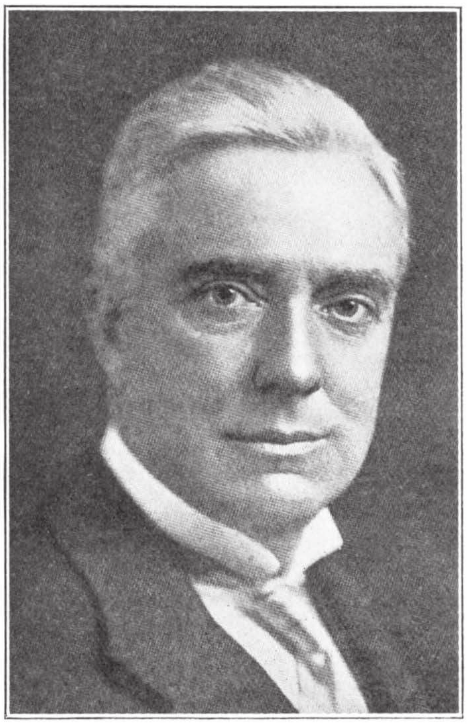
THE BIRTH AND BABYHOOD OF THE TELEPHONE.

DR. WATSON'S ADDRESS.

I am to speak to you of the birth and babyhood of the telephone, and something of the events which preceded that important occasion. These are matters that must seem to you ancient history; in fact, they seem so to me, although the events all happened in the years 1874 to 1880.

The occurrences of which I shall speak, lie in my mind as a splendid drama, in which it was my great privilege to play a part. I shall try to put myself back into that wonderful play, and tell you its story from the same attitude of mind I had then—the point of view of a mere boy, just out of his apprenticeship as an electro-mechanician, intensely interested in his work, and full of boyish hope and enthusiasm. Therefore, as it must be largely a personal narrative, I shall ask you to excuse my many "I's" and "my's" and to be indulgent if I show how proud and glad I am that I was chosen by the fates to be the associate of Alexander Graham Bell, to work side by side with him day and night through all these wonderful happenings that have meant so much to the world.

The Williams' Electrical Workshop.—I realize now what a lucky boy I was, when at 13 years of age I had to leave school and go to work for my living, although I didn't think so at that time. I am not advising my young friends to leave school at this age, for they may not have the opportunity to enter college as I did at 40. There's a "tide in the affairs of men," you know, and that was the beginning of its flood in my life, for after trying several vocations—clerking, bookkeeping, carpentering, etc.—and finding them all unattractive, I at last found just the job that suited me in the electrical workshop of Charles Williams, at 109, Court Street, Boston—one of the best men I have ever known. Better luck couldn't befall a boy than to be brought so early in life under the influence



Thomas A Watson
November 13th 1928

of such a high-minded gentleman as Charles Williams.

I want to say a few words about my work there, not only to give you a picture of such a shop in the early '70's but also because in this shop the telephone had its birth and a good deal of its early development.

I was first set to work on a hand lathe turning binding posts for five dollars a week. The mechanics of to-day with their automatic screw machines, hardly know what it is to turn little rough castings with a hand tool. How the hot chips used to fly into our eyes! One day I had a fine idea. I bought a pair of 25 cent. goggles, thinking the others would hail me as a benefactor of mankind and adopt my plan. But they laughed at me for being such a sissy boy and public opinion forced me back to the old time honored plan of winking when I saw a chip coming. It was not an efficient plan, for the chip usually got there first. There was a liberal education in it for me in manual dexterity. There was no specializing in these shops at that time. Each workman built everything there was in the shop to build, and an apprentice also had a great variety of jobs, which kept him interested all the time, for his tools were poor and simple and it required lots of thought to get a job done right.

There were few books on electricity published at that time. Williams had copies of most of them in his show case, which we boys used to read noons, but the book that interested me most was Davis' Manual of Magnetism, published in 1847, a copy of which I made mine for 25 cents. If you want to get a good idea of the state of the electrical art at that time, you should read that book. I found it very stimulating and that same old copy in all the dignity of its dilapidation has a place of honour on my book shelves to-day.

My promotion to higher work was rapid. Before two years had passed, I had tried my skill on about all the regular work of the establishment — call bells, annunciators, galvanometers, telegraph keys, sounders, relays, registers and printing telegraph instruments.

Individual initiative was the rule in Williams' shop—we all did about as we pleased. Once I built a small steam engine for myself during working hours, when business was slack. No one objected. That steam engine, by the way, was the embryo of the biggest shipbuilding plant in the United States to-day, which I established some ten years later with telephone profits, and which now employs more than 4,000 men.

Such was the electrical shop of that day. Crude and small as they were, they were the forerunners of the great electrical works of to-day. In them were being trained the men who were among the leaders in the wonderful development of applied electricity which began soon after the time of which I am to speak. Williams, although he never had at that time more than 30 or 40 men working for him, had one of the largest and best fitted shops in the country. I think the Western Electric shop at Chicago was the only larger one. That was also undoubtedly better organized and did better work than Williams'. When a piece of machinery built by the Western Electric came into our shop for repairs, we boys always used to admire the superlative excellence of the workmanship.

Experience with Inventors.—Besides the regular work at Williams', there was a constant stream of wild-eyed inventors, with big ideas in their heads and little money in their pockets, coming to the shop to have their ideas tried out in brass and iron. Most of them had an "angel" whom they had hypnotized into paying the bills. My enthusiasm, and perhaps my sympathetic nature, made me a favourite workman with those men of visions, and in 1873-74 my work had become largely making experimental apparatus for such men. Few of their ideas ever amounted to anything, but I liked to do the work, as it kept me roaming in fresh fields and pastures new all the time. Had it not been, however, for my youthful enthusiasm—always one of my chief assets—I fear this experience would have made me so sceptical and cynical as to the value of electrical inventions that my future prospects might have been injured.

I remember one limber-tongued patriarch who had induced some men to subscribe 1,000 dollars to build what he claimed to be an entirely new electric engine. I made much of it for him. There was nothing new in the engine, but he intended to generate his electric current in a series of iron tanks the size of trunks, to be filled with nitric acid with the usual zinc plates suspended therein. When the engine was finished and the acid poured into the tanks for the first time, no one waited to see the engine run, for inventor, "angel," and workmen, all tried to see who could get out of the shop quickest. I won the race as I had the best start.

I suppose there is just such a crowd of crude minds still besieging the workshops, men who seem incapable of finding out what has been already done, and so keep on year after year, threshing old straw.

The "Harmonic Telegraph."—All the men I worked for at that time were not of that type. There were a very few different. Among them, dear old Moses G. Farmer, perhaps the leading practical electrician of that day. He was full of good ideas, which he was constantly bringing to Williams to have worked out. I did much of his work and learned from him more about electricity than ever before or since. He was electrician at that time for the United States Torpedo Station at Newport, Rhode Island, and in the early winter of 1874, I was making for him some experimental torpedo exploding apparatus. That apparatus will always be connected in my mind with the telephone, for one day when I was hard at work on it, a tall, slender, quick-motioned man with pale face, black side whiskers, and drooping mustache, big nose and high sloping forehead crowned with bushy, jet black hair, came rushing out of the office and over to my work bench. It was Alexander Graham Bell whom I saw then for the first time. He was bringing to me a piece of mechanism which I had made for him under instructions from the office. It had not been made as he had directed and he had broken down the rudimentary discipline of the shop in coming directly to me to get it altered. It was a receiver and a transmitter of his "Harmonic Telegraph," an invention of his with which he was then endeavouring to win fame and fortune. It was a simple affair by means of which, utilizing the law of sympathetic vibration, he expected to send six or eight Morse messages on a single wire at the same time, without interference.

Although most of you are probably familiar with the device, I must, to make my story clear, give you a brief description of the instruments, for though Bell never succeeded in perfecting his telegraph, his experimenting on it led to a discovery of the highest importance.

The essential parts of both transmitter and receiver were an electro-magnet and a flattened piece of steel clock spring. The spring was clamped by one end to one pole of the magnet, and had its other end free to vibrate over the other pole. The transmitter had, besides this, make-and-break points like an ordinary vibrating bell which, when the current was on, kept the spring vibrating in a sort of nasal whine, of a pitch corresponding to the pitch of the spring. When the signalling key was closed, an electrical copy of that whine passed through the wire and the distance receiver. There were, say, six transmitters with their springs tuned to six different pitches and six receivers with their springs tuned to correspond. Now, theoretically, when a transmitter sent its electrical whine into the line wire, its own faithful receiver spring at the distant station would wriggle sympathetically but all the others on the same line would remain coldly quiescent. Even when all the transmitters were whining at once through their entire gamut, making a row as if all the miseries this world of trouble ever produced were concentrated there, each receiver spring along the line would select its own from that sea of troubles and ignore all the others. Just see what a simple, sure-to-work invention this was; for just break up those various whines into the dots and dashes of Morse messages and one wire would do the work of six, and the "Duplex" telegraph that had just been invented would be beaten to a frazzle. Bell's reward would be immediate and rich, for the "Duplex" had been bought by the Atlantic and Pacific Telegraph Company, giving them a great advantage over their only competitor, the Western Union Company, and the latter would, of course, buy Bell's invention and his financial problems would be solved.

All this was, as I have said, theoretical, and it was mighty lucky for Graham Bell that it was, for had his harmonic telegraph been a well behaved apparatus that always did what its parent wanted it to do, the speaking telephone might never have emerged from a certain marvellous conception, that had even then been surging back of Bell's high forehead for two or three years. What that conception was, I soon learned, for he couldn't help speaking about it, although his friends tried to hush it up. They didn't like to have him get the reputation of being visionary, or—something worse.

To go on with my story; after Mr. Farmer's peace making machines were finished, I made half a dozen pairs of the harmonic instruments for Bell. He was surprised, when he tried them to find that they didn't work as well as he expected. The cynical Watson wasn't at all surprised for he had never seen anything electrical yet that worked at first the way the inventor thought it would. Bell wasn't discouraged in the least and a long course of experiments followed which gave me a steady job that winter and brought me into close contact with a wonderful personality that did more to mould my life rightly than anything else that ever came into it.

I became mightily tired of those " whiners " that winter. I called them by that name, perhaps, as an inadequate expression of my disgust with their persistent perversity, the struggle with which soon began to take all the joy out of my young life, not being endowed with the power of Macbeth's weird sister to

" Look into the seeds of time,
And say which grain will grow and which
will not."

Let me say here, that I have always had a feeling of respect for Elisha Gray, who, a few years later, made that harmonic telegraph work, and vibrate well-behaved messages, that would go where they were sent, without fooling with every receiver on the line.

Most of Bell's early experimenting on the harmonic telegraph was done in Salem, at the home of Mrs. George Sanders, where he resided for several years, having charge of the instruction of her deaf nephew. The present Y.M.C.A. building is on the site of that house. I would occasionally work with Bell there, but most of his experimenting in which I took part was done in Boston.

Bell's Theory of Transmitting Speech.—Mr. Bell was very apt to do his experimenting at night, for he was busy during the day at the Boston University, where he was Professor of Vocal Physiology, especially teaching his father's system of visible speech, by which a deaf mute might learn to talk—quite significant of what Bell was soon to do in making mute metal talk. For this reason I would often remain at the shop during the evening to help him test some improvement he had had me make on the instruments.

One evening when we were resting from our struggles with the apparatus, Bell said to me: " Watson, I want to tell you of another idea I have, which I think will surprise you." I listened, I suspect, somewhat languidly, for I must have been working that day about sixteen hours, with only a short nutritive interval, and Bell had already given me, during the weeks we had worked together, more new ideas on a great variety of subjects, including visible speech, elocution and flying machines, than my brain could assimilate, but when he went on to say that he had an idea by which he believed it would be possible to talk by telegraph, my nervous system got such a shock that the tired feeling vanished. I have never forgotten his exact words; they have run in my mind ever since like a mathematical formula. " If," he said, " I could make a current of electricity vary in intensity, precisely as the air varies in density during the production of a sound, I should be able to transmit speech telegraphically." He then sketched for me an instrument that he thought would do this, and we discussed the possibility of constructing one. I did not make it; it was altogether too costly, and the chances of its working too uncertain to impress his financial backers—Mr. Gardiner G. Hubbard and Mr. Thomas Sanders—who were insisting that the wisest thing for Bell to do was to perfect the harmonic telegraph; then he would have the money and leisure enough to build air castles like the telephone.

June 2nd, 1875.—I must have done other work in the shop besides Bell's during the winter and spring of 1875, but I cannot remember a single item of it. I do remember that when I was not working for Bell I was thinking of his ideas. All through my recollection of that period runs that nightmare—the harmonic telegraph, the ill working of which got on my conscience, for I blamed my lack of mechanical skill for the poor operation of an invention apparently so simple. Try our best, we could not make that thing work rightly, and Bell came as near to being discouraged as I ever knew him to be.

But this spring of 1875 was the dark hour just before the dawn.

If the exact time could be fixed, the date when the conception of the undulatory or speech-transmitting current took its perfect form in Bell's mind would be the greatest day in the history of the telephone, but certainly June 2nd, 1875, must always rank next; for on that day the mocking fiend inhabiting that demonaic telegraph apparatus, just as a now-you-see-it-and-now-you-don't sort of a satanic joke, opened the curtain that hides from man great Nature's secrets and gave us a glimpse as quick as if it were through the shutter of a snap-shot camera, into that treasury of things not yet discovered. That imp didn't do this in any kindly, helpful spirit—any inventors knows he isn't that kind of a being—he just meant to tantalize and prove that a man is too stupid to grasp a secret, even if it is revealed to him. But he hadn't properly estimated Bell, though he had probably sized me up all right. That glimpse was enough to let Bell see and seize the very thing he had been dreaming about and drag it out into the world of human affairs.

The Telephone Born.

Coming back to earth, I'll try and tell you what happened that day. In the experiments on the harmonic telegraph, Bell had found that the reason why the messages got mixed up was inaccuracy in the adjustment of the pitches of the receiver springs to those of the transmitter. Bell always had to do this tuning himself, as my sense of pitch and knowledge of music were quite lacking—a faculty (or lackulty) which you will hear later became quite useful. Mr. Bell was in the habit of observing the pitch of a spring by pressing it against his ear while the corresponding transmitter in a distant room was sending its intermittent current through the magnet of that receiver. He would then manipulate the tuning screw until that spring was tuned to accord with the pitch of the whine coming from the transmitter. All this experimenting was carried on in the upper story of the Williams building, where we had a wire connecting two rooms perhaps sixty feet apart looking out on Court Street.

Realization.—On the afternoon of June 2nd, 1875, we were hard at work on the same old job, testing some modification of the instruments. Things were badly out of tune that afternoon in that hot garret, not only the instruments, but, I fancy, my enthusiasm and my temper though Bell was as energetic as ever. I had charge of the transmitters as usual, setting them squealing one after the other, while Bell was retuning the receiver springs one by one, pressing them against his ear as I have described. One of the transmitter springs I was attending to stopped vibrating and I plucked it to start it again. It didn't start and I kept on plucking it, when suddenly I heard a shout from Bell in the next room, and then out he came with a rush, demanding, "What did you do then? Don't change anything. Let me see!" I showed him. It was very simple. The contact screw was screwed down so far that it made permanent contact with the spring, so that when I snapped the spring the circuit had remained unbroken while the strip of magnetized steel by its vibration over the pole of its magnet, was generating that marvellous conception of Bell's—a current of electricity that varied in intensity precisely as the air was varying in density within hearing distance of that spring. That undulatory current had passed through the connecting wire to the distant receiver which, fortunately, was a mechanism that could transform that current back into an extremely faint echo of the sound of the vibrating spring that had generated it, but what was still more fortunate, the right man had that mechanism at his ear during that fleeting moment, and instantly recognized the transcendent importance of that faint sound thus electrically transmitted. The shout I heard and his excited rush into my room where the result of that recognition. The speaking telephone was born at that moment. Bell knew perfectly well that the mechanism that could transmit all the complex vibrations of one sound could do the same for any sound, even that of speech. That experiment showed him that the complex apparatus he had thought would be needed to accomplish that long dreamed result was not at all necessary, for here was an extremely simple mechanism operating in a perfectly obvious way, that could do it perfectly. All the experimenting that followed that discovery, up to the time the telephone was put into practical use was largely a matter of working out the details.

We spent a few hours verifying the discovery, repeating it with all the differently tuned springs we had, and before we parted that night Bell gave me directions for making the first electric speaking telephone. I was to mount a small drumhead of gold beater's skin over one of the receivers, join the centre of the drumhead to the free end of the receiver spring and arrange a mouthpiece over the drumhead to talk into. His idea was to force the steel spring to follow the vocal vibrations and generate a current of electricity that would vary in intensity as the air varies in density during the utterance of speech sounds. I followed these directions and had the instrument ready for its trial the very next day. I rushed it, for Bell's excitement and enthusiasm over the discovery had aroused mine again, which had been sadly dampened during those last few weeks by the meagre results of the harmonic experiments. I made every part of that first telephone myself, but I didn't realize while I was working on it what a tremendously important piece of work I was doing.

The First Telephone Line.

The two rooms in the attic were too near together for the test, as our voices would be heard through the air, so I ran a wire especially for the trial from one of the rooms in the attic down two flights to the third floor where Williams' main shop was, ending it near my work bench at the back of the building. That was the first telephone line. You can well imagine that both our hearts were beating above the normal rate, while we were getting ready for the trial of the new instrument that evening. I got more satisfaction from the experiment than Mr. Bell did, for shout my best I could not make him hear me, but I could hear his voice and almost catch the words. I rushed up stair and told him what I had heard. It was enough to show him that he was on the right track, and before he left that night he gave me directions for several improvements in the telephones I was to have ready for the next trial.

I hope my pride in the fact that I made the first telephone, put up the first telephone wire and heard the first words ever uttered through a telephone, has never been too ostentatious and offensive to my friends, but I am sure that you will grant that a reasonable amount of that human weakness is excusable in me. My pride has been tempered to quite a bearable degree by my realization that the reason why I heard Bell in that first trial of the telephone and he did not hear me, was the vast superiority of his strong vibratory tones over any sound my undeveloped voice was then able to utter. My sense of hearing, however, has always been unusually acute, and that might have helped to determine this result.

The building where these first telephone experiments were made is still in existence. It is now used as a theatre. The lower stories have been much altered, but that attic is still quite unchanged and a few weeks ago I stood on the very spot where I snapped those springs and helped test the first telephone thirty-seven years and seven months before.

Mr. Watson Heard the Fist Sentence Ever Spoken Over the Telephone.—Of course, in our struggle to expel the imps from the invention, an immense amount of experimenting had to be done, but it wasn't many days before we could talk back and forth and hear each other's voice. It is, however, hard for me to realize now that it was not until the following March that I heard a complete and intelligible sentence. It made such an impression upon me that I wrote that first sentence in a book I have always preserved. The occasion had not been arranged and rehearsed as I suspect the sending of the first message over the Morse telegraph had been years before, for instead of that noble first telegraphic message—" What hath God wrought ? " the first message of the telephone was : " Mr. Watson, come here, I want you." Perhaps, if Mr. Bell had realized that he was about to make a bit of history, he would have been prepared with a more sounding and interesting sentence.

Soon after the first telephones were made, Bell hired two rooms on the top floor of an inexpensive boarding house at No. 5, Exeter Place, Boston, since demolished to make room for mercantile buildings. He slept in one room; the other he fitted up as a laboratory. I ran a wire for him between the two rooms and after that time practically all his experimenting was done there. It was here one evening when I had gone there to help him test some improvement and to spend the night with him, that I heard the first complete sentence I have just told you about. Matters began to move more rapidly and during the summer of 1876, the telephone was talking so well that one didn't have to ask the other man to say it over again more than three or four times before one could understand quite well, if the sentences were simple.

The Centennial Exposition.—This was the year of the Centennial Exposition at Philadelphia, and Bell decided to make an exhibit there. I was still working for Williams, and one of the jobs I did for Bell was to construct a telephone of each form that had been devised up to that time. These were the first nicely finished instruments that had been made. There had been no money nor time to waste on polish or non-essentials. But these Centennial telephones were done up in the highest style of the art. You could see your face in them. These aristocratic telephones worked finely, in spite of their glitter, when Sir William Thompson tried them at Philadelphia that summer. I was as proud as Bell himself, when I read Sir William's report, wherein he said after giving an account of the tests: "I need hardly say I was astonished and delighted, so were the others who witnessed the experiment and verified with their own ears the electric transmission of speech. This, perhaps, the greatest marvel hitherto achieved by electric telegraph, has been obtained by appliances of quite a homespun and rudimentary character." I have never forgiven Sir William for that last line. Homespun!

However, I recovered from this blow, and soon after Mr. Gardiner G. Hubbard, afterwards Mr. Bell's father-in-law, offered me an interest in Bell's patents if I would give up my work at Williams' and devote my time to the telephone. I accepted, although I wasn't altogether sure it was a wise thing to do from a financial standpoint. My contract stipulated that I was to work under Mr. Bell's directions, on the harmonic telegraph as well as on the speaking telephone, for the two men who were paying the bills still thought there was something in the former invention, although very little attention had been given to its vagaries after the June 2nd discovery.

I moved my domicile from Salem to another room on the top floor at 5, Exeter Place, giving us the entire floor, and as Mr. Bell had lost most of his pupils by wasting so much of his time on telephones, he could devote nearly all his time to the experimenting. Then followed a period of hard and continuous work on the invention. I made telephones with every modification and combination of their essential parts that either of us could think of. I made and we tested telephones with all sizes of diaphragms made of all kinds of materials—diaphragms of boiler iron several feet in diameter, down to a miniature affair made of the bones and drum of a human ear, and found that the best results came from an iron diaphragm of about the same size and thickness as is used to-day. We tested electro magnets and permanent magnets, of a multitude of sizes and shapes, with long cores and short cores, fat cores and thin cores, solid cores and cores of wire, with coils of many sizes, shapes and resistances and mouthpieces of an infinite variety. Out of the hundreds of experiments there emerged practically the same telephone you take off the hook and listen with to-day, although it was then transmitter as well as receiver.

"Talking" from Boston to Cambridge.—Progress was rapid, and on October 9th, 1876, we were ready to take the baby out doors for the first time. We got permission from the Walworth Manufacturing Company to use their private wire running from Boston to Cambridge, about two miles long. I went to Cambridge that evening with one of our best telephones, and waited until Bell signalled from the Boston office on the Morse sounder. Then I cut out the sounder and connected in the telephone and listened. Not a murmer came through! Could it be that, although the thing worked all right in the house, it wouldn't work

under practical line conditions? I knew that we were using the most complex and delicate electric current that had ever been employed for a practical purpose and that it was extremely "intense," for Bell had talked through the circuit composed of 20 or 30 human beings joined hand to hand. Could it be, I thought, that these high tension vibrations leaking off at each insulator along the line, had vanished completely before they reached the Charles river? That fear passed through my mind as I worked over the instrument, adjusting it and tightening the wires in the binding posts, without improving matters in the least. Then the thought struck me that perhaps there was another Morse sounder in some other room. I traced the wires from the place they entered the building and sure enough I found a relay with a high resistance coil in the circuit. I cut it out with a piece of wire across the binding posts and rush back to my telephone and listened. That was the trouble. Plainly as one could wish came Bell's "ahoy,"* I ahoyed back, and the first long distance telephone conversation began. Sceptics had been objecting that the telephone could never compete with the telegraph as its messages would not be accurate. For this reason Bell had arranged that we should make a record of all we said and heard that night, if we succeeded in talking at all. We carried out this plan and the entire conversation was published in parallel columns in the next morning's *Advertiser,* as the lastest startling scientific achievement. Infatuated with the joy of talking over an actual telegraph wire, we kept up our conversation until long after midnight. It was a very happy boy that travelled back to Boston in the small hours with the telephone under his arm done up in a newspaper. Bell had taken his record to the newspaper office and was not at the laboratory when I arrived there, but when he came in there ensued a jubilation and war dance that elicited next morning from our landlady, who wasn't at all scientific in her tastes, the remark that we'd have to vacate if we didn't make less noise at nights.

Tests on still longer telegraph lines soon followed—the success of each experiment being in rather exact accordance with the condition of the poor, rusty-joined wires we had to use. Talk about imps that baffle inventors! There was one of an especially vicious and maligant type in every unsoldered joint of the old wires. The genial Tom Doolittle hadn't even thought of his hard drawn copper wire then, with which he later eased the lot of the struggling telephone men.

Our Many Visitors.—Meanwhile the fame of the invention had spread rapidly abroad and all sorts of people made pilgrimages to Bell's laboratory to hear the telephone talk. A list of the scientists who came to the attic of that cheap boarding house to see the telephone would read like the roster of the American Association for the Advancement of Science. My old electrical mentor, Moses G. Farmer, called one day to see the latest improvements. He told me then with tears in his eyes when he first read a description of Bell's telephone he couldn't sleep for a week, he was so mad with himself for not discovering the thing years before. "Watson," said he, "that thing has flaunted itself in my very face a dozen times within the last ten years and every time I was too blind to see it. But," he continued, "if Bell had known anything about electricity he would never have invented the telephone."

Two of our regular visitors were young Japanese pupils of Professor Bell—very polite, deferential, quiet, bright-eyed little men, who saw everything and made cryptic notes. They took huge delight in proving that the telephone could talk Japanese. A curious effect of the telephone I noticed at that time was its power to paralyze the tongues of men otherwise fluent enough by nature and profession. I remember a prominent lawyer, who, when he heard my voice in the telephone making some such profound remark to him as "How do you do," could only reply, after a long pause, "Rig a jig jig and away we go."

TELEPHONE INSTALLATION.

We began to get requests for telephone installations long before we were ready to supply them. In April, 1877, the first out door telephone line was run between Mr. Williams' office at 109, Court Street, and his house in Somerville. Professor Bell and I were present and participated in the important ceremony of opening the line and the event was a headliner in the next morning's papers.

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* *"Ahoy!" was the telephone shout, and was used during the experiments, but "hello!" superseded it when the telephone got into practical use.*

Fiancial Problems.—At about this time Professor Bell's financial problems had begun to press hard for solution. We were very much disappointed because the President of the Western Union Telegraph Company had refused, somewhat contemptuously, Mr. Hubbard's offer to sell him all the Bell patents for the exhorbitant sum of 100,000 dollars. It was an especially hard blow to me, for while the negotiations were pending I had had visions of a sumptuous office in the Western Union Building in New York which I was expecting to occupy as Superintendent of the Telephone Department of the great telegraph company. However, we recovered even from that facer. Two years later the Western Union would gladly have bought those patents for 25,000,000 dollars.

But before that happy time there were lots of troubles of all the old and of several new varieties to be surmounted. Professor Bell's particular trouble in the Spring of 1877, arose from the fact that he had fallen in love with a most charming young lady. I had never been in love myself at that time and that was my first opportunity of observing what a serious matter it can be, especially when the father isn't altogether enthusiastic. I rather suspected at that time that that shrewd but kind-hearted gentleman put obstacles in the course of that true love, in order to stimulate the young man to still greater exertion in perfecting his inventions. But he might have thought as Prospero did:

> "They are both in either's power; but this
>   swift business
> I must uneasy make, lest too light winning
> Make the prize light."

Bell's immediate financial needs were solved, however, by the demand that began at this time for public lectures by him on the telephone. It is hard to realize to-day what an intense and widespread interest there was then in the telephone. I don't believe any new invention could stir the public to-day as the telephone did then, surfeited as we are now with the wonderful things that have been invented since.

Telephone Lectures.—Bell's first lecture, as I have said, was given before a well-known scientific society—the Essex Institute—at Salem, Mass. They were especially interested in the telephone because Bell was living at Salem during the early telephone experiments. The first lecture was free to members of the society, but it packed the hall and created so much interest that Bell was requested to repeat it for an admission fee. This he did to an audience that again filled the house. Requests for lectures poured in upon Bell after that. Such men as Oliver Wendell Holmes and Henry W. Longfellow signed the request for the Boston lectures. The Salem lectures were soon followed by a lecture in Providence to an audience of 2,000, by a course of three lectures at the largest hall in Boston—all three packed—by three in Chickering Hall, New York, and by others in most of the large cities of New England. They all took place in the Spring and early Summer of 1877, during which time there was little opportunity for experimenting for either Bell or myself, which I think now was rather a good thing, for we had become quite stale and needed a change that would give us a new influx of ideas. My part in the lectures was important, although entirely invisible as far as the audience was concerned. I was always at the other end of the wire, generating and transmitting to the hall where Professor Bell was speaking, such telephonic phenomena as he needed to illustrate his lectures. I would have at my end circuit breakers—rheotomes, we called them—that would utter electric howls of various pitches, a lusty cornet player, sometimes a small brass band, and an electric organ with Edward Wilson to play on it, but the star performer was the young man who two years before didn't have voice enough to let Bell hear his own telephone, but in whom that two years of strenuous shouting into mouthpieces of various sizes and shapes had developed a voice with the carrying capacity of a steam calliope. My special function in these lectures was to show the audience that the telephone could really talk. Not only that, I had to do all the singing, too, for which my musical deficiences fitted me admirably.

My Telephone Entertainers.—Professor Bell would have one telephone by his side on the stage where he was speaking, and three or four others of the big box variety we used at that time would be suspended about the hall, all connected by means of a hired telegraph wire with the place where I was stationed, from five to twenty-five miles away. Bell would give the audience, first, the commonplace parts of the show and then would come the thrillers of the evening—my shouts and songs. I would shout such sentences as, "How do you do," "Good evening," "What do you think of the telephone?" which they could all hear, although the words issued from the mouthpieces rather badly marred by the defective talking powers of the telephones of that date. Then I would sing "Hold the Fort," "Pull for the Shore," "Yankee Doodle," and as a delicate allusion to the Professor's nationality, "Auld Lang Syne." My sole sentimental song was "Do Not Trust Him, Gentle Lady." This repertoire always brought down the house. After every song I would listen at my telephone for further directions from the lecturer, and always felt the artist's joy when I heard in it the long applause that followed each of my efforts. I was always encored to the limit of my repertoire and sometimes had to sing it through twice.

I have always understood that Professor Bell was a fine platform speaker but this is entirely hearsay on my part for, although I spoke at every one of his lectures, I have never yet had the pleasure of hearing him deliver an address.

First Sound-Proof Booth.—In making the preparations for the New York lectures I incidentally invented the sound-proof booth, but as Mr. Lockwood was not then associated with us, and for other reasons, I never patented it. It happened thus: Bell thought he would like to astonish the New Yorkers by having his lecture illustrations sent all the way from Boston. To determine whether this was practicable, he made arrangements to test the telephones a few days before on one of the Atlantic and Pacific wires. The trial was to take place at midnight. Bell was at the New York end, I was in the Boston laboratory. Having vividly in mind the strained relations already existing with our landlady, and realizing the carrying power of my voice when I really let it go, as I knew I should, have to that night, I cast about for some device to deaden the noise. Time was short and appliances scarce, so the best I could do was to take the blankets off our beds and arrange them in a sort of loose tunnel, with the telephone tied up in one end and the other end open for the operator to crawl into. Thus equipped I awaited the signal from New York announcing that Bell was ready. It came soon after midnight. Then I connected in the telephone, deposited myself in that cavity, and shouted and listened for two or three hours. It didn't work as well as it might. It is a wonder some of my remarks didn't burn holes in the blankets. We talked after a fashion but Bell decided it wasn't safe to risk it with a New York audience. My sound-proof booth, however, was a complete success, as far as stopping the sound was concerned, for I found by cautious inquiry next day that nobody had heard my row. Later inventors improved my booth, making it more comfortable for a pampered public but not a bit more sound-proof.

"*The Suppostitious Mr. Watson.*"—One of those New York lectures looms large in my memory on account of a novel experience I had at my end of the wire. After hearing me sing, the manager of the lectures decided that while I might satisfy a Boston audience I would never do for a New York congregation, so he engaged a fine baritone soloist—a powerful negro, who was to assume the singing part of my program. Being much better acquainted with the telephone than that manager was I had doubts about the advisability of this change in the cast. I didn't say anything, as I didn't want to be accused of professional jealousy, and I knew my repertoire would be on the spot in case things went wrong. I was stationed that night at the telegraph office at New Brunswick, New Jersey, and I and the rest of the usual appliances of that end of the lecture went down in the afternoon to get things ready. I rehearsed my rival and found him a fine singer but had difficulty in getting him to crowd his lips into the mouthpiece. He was handicapped for the telephone business by being musical, and he didn't like the sound of his voice jammed up in that way. However, he promised to do what I wanted when it came to the actual work of the evening, and I went to supper. When I returned to the telegraph office, just before eight o'clock, I found to my horror that the young lady operator had invited six or eight of her dear friends to witness the interesting proceedings. Now, besides my musical deficiencies, I had another qualification as a telephone man—I was very modest; in fact, in the presence of ladies, extremely bashful. It didn't trouble me in the least to talk or sing to a great audience, provided, of course, it was a few miles away, but when I saw those girls, the complacency with which I had been contemplating the probable failure of my fine singer was changed to painful apprehension. If he wasn't successful a very bashful young man would have a new experience. I should be obliged to sing myself before those giggling, unscientific girls. This world would be a better place to live in if we all tried to help our fellow-men succeed, as I tried that night, when the first song was called for, to make my musical friend achieve a lyrical triumph on the Metropolitan stage. But he sang that song for the benefit of those girls, not for Chickering Hall, and it was with a heavy heart that I listened for Bell's voice when he finished it. The blow fell. In his most delightful platform tones, Bell uttered the fatal words I had foreboded, " Mr. Watson, the audience could not hear that. Won't you please sing? " Bell was always a kind-hearted man, but he didn't know. However, I nerved myself with the thought that that New York audience, made sceptical by the failure of that song, might be thinking cynical things about my beloved leader and his telephone, so I turned my back on those girls and made that telephone rattle with the stirring strains of " Hold the Fort," as it never had before. Then I listened again, Ah, the sweetness of appreciation! That New York audience was applauding vigorously. When it stopped, the same voice came with a new note of triumph in it. " Mr. Watson, the audience heard that perfectly and call for an encore." I sang through my entire repertoire and began again on " Hold the Fort," before the audience was satisfied. That experience did me good, I have never had stage fright since. But the " suppostitious Mr. Watson," as they called me then, had to do the singing at all of Bell's subsequent lectures. Nobody else had a chance at the job; one experience was enough for Mr. Bell.

My baritone had his hat on his head and a cynical expression on his face, when I finished working on those songs. " Is that what you wanted? " he asked. " Yes." " Well, boss, I couldn't do that." Of course he couldn't.

An Exhibition in Lawrence.—Another occasion is burnt into my memory that wasn't such a triumph over difficulties. In these lectures we always had another trouble to contend with, besides the rusty joints in the wires; that was the operators cutting in, during the lectures, their highest resistance relays, which enabled them to hear some of the intermittent current effects I sent to the hall. Inductance, retardation, and all that sort of thing which you have so largely conquered since, were invented long before the telephone was, and were awaiting her on earth all ready to slam it when Bell came along. Bell lectured at Lawrence, Massachusetts, one evening in May, and I prepared to furnish him with the usual program from the laboratory in Boston.

But the wire the company assigned us was the worst yet. It worked fairly well when we tried it in the afternoon, but in the evening every station on the line had evidently cut in its relay, and do my best I couldn't get a sound through to the hall.

The local newspaper generally sent a reporter to my end of the wire to write up the occurrences there. This is the report of such an envoy as it appeared in the Lawrence paper the morning after Bell's lecture there:

" Mr. Fisher returned this morning. He says that Watson, the organist and himself occupied the laboratory, sitting in their shirt sleeves with their collars off. Watson shouted his lungs into the telephone mouthpiece, 'Hoy! Hoy! Hoy!' and receiving no response inquired of Fisher if he pardoned for a little ' hamburg edging' on his language. Mr.

Fisher endeavoured to transmit to his Lawrence townsmen the tune of ' Federal Street ' played upon the cornet, but the air was not distinguishable here. About 10 p.m., Watson discovered the ' Northern Lights ' and found his wires alive with lightning, which was not included in the original scheme of the telephone. He says the loose electricity abroad in the world was too much for him."

Waiting for Watson.—The next morning a poem appeared in the Lawrence paper. The writer must have sat up all night to write it. It was entitled " Waiting for Watson," and I am very proud of the only poem I ever had written about me. I am going to ask your permission to read it. Please notice the great variety of human feeling the poet put into it. It even suggests missiles, though it flings none.

Lawrence, Mass., *Daily American*, Tuesday, May 29, 1877.

WAITING FOR WATSON.

To the great hall we strayed,
Fairly our fee we paid,
Seven hundred there delayed,
But, where was Watson?

Seven hundred souls were there,
Waiting with stony stare,
In that expectant air—
Waiting for Watson.

Oh, how our ears we strained,
How our hopes waxed and waned,
Patience to dregs we drained,
Yes, we did, Watson!

Give but one lusty groan,
For bread we'll take a stone,
Ring your old telephone!
Ring, brother Watson.

Doubtless 'tis very fine,
When, all along the line,
Things work most superfine—
Doubtless 'tis Watson.

We know that, every day,
Schemes laid to work and pay,
Fail and " gang aft a-gley "—
Often, friend Watson.

And we'll not curse, or fling,
But, next time, do the thing
And we'll all rise and sing,
" Bully for Watson! "

Or, by the unseen powers,
Hope in our bosom sours,
No telephone in ours—
" Please, Mr. Watson."

My last Public Appearance.—But my vacation was about over. Besides raising the wind, the lectures had stirred up a great demand for telephone lines. The public was ready for the telephone long before we were ready for the public, and this pleasant artistic interlude had to stop; I was needed in the shop to build some telephones to satisfy the insistent demand. Fred Gower, a young newspaper man of Providence, had become interested with Mr. Bell in the lecture work. He had an unique scheme for a dual lecture with my illustrations sent from a central point to halls in two cities at the same time. I think my last appearance in public was at one of these dualities. Bell lectured at New Haven and Gower gave the talk at Hartford, while I was in between at Middletown, Conn., with my apparatus, including my songs. It didn't work very well. The two lecturers didn't speak synchronously. Gower told me afterwards that I was giving him, " How do you do," when he wanted " Hold the Fort," and Bell said I made it awkward for him by singing " Do Not Trust Him, Gentle Lady," when he needed the trombone solo.

The " Gower-Bell " Telephone.—In the following August, Professor Bell married and went to England, taking with him a complete set of up-to-date telephones, with which he intended to start the trouble in that country. Fred Gower became so fascinated with lecturing on the telephone that he gave up an exclusive right Mr. Hubbard had granted him for renting telephones all over New England, for the exclusive privilege of using the telephone for lecture purposes all over the United States. But it wasn't remunerative after Bell and I gave it up. The discriminating public preferred Mr. Bell as speaker—and I always felt that the singing never reached the early heights.

Gower went to England later. There he made some small modification of Bell's telephone, called it the " Gower-Bell " telephone, and made a fortune out of his hyphenated atrocity. Later he married Lilian Nordica, although she soon separated from him. He became interested in ballooning. The last scene in his life before the curtain dropped showed a balloon over the waters of the English Channel. A fishing boat hails him, "Where are you bound?" Gower's voice replies, "To London." Then the balloon and its pilot drifted into the mist for ever.

Developing a Calling Apparatus; the Watson "Buzzer."—As I said, I went back to work, and my next two years was a continuous performance. It began to dawn on us that people engaged in getting their living in the ordinary walks of life couldn't be expected to keep the telephone at their ear all the time waiting for a call, especially as it weighed about ten pounds then and was as big as a small packing case, so it devolved on me to get up some sort of a call signal. Williams on his line used to call by thumping the diaphragm through the mouthpiece with the butt of a lead pencil. If there was someone close to the telephone at the other end, and it was very still, it did pretty well, but it seriously damaged the vitals of the machine and therefore I decided it wasn't really practical for the general public; besides we might have to supply a pencil with every telephone and that would be expensive. Then I rigged a little hammer inside the box with a button on the outside. When the button was thumped the hammer would hit the side of the diaphragm where it could not be damaged, the usual electrical transformation took place, and a much more modest but still unmistakable thump would isue from the telephone at the other end.

That was the first calling apparatus ever devised for use with the telephone, not counting Williams' lead pencil, and several with that attachment were put into practical use. But the exacting public wanted something better, and I devised the Watson "Buzzer"—the only practical use we ever made of the harmonic telegraph relics. Many of these were sent out. It was a vast improvement on the Watson "Thumper," but still it didn't take the popular fancy. It made a sound quite like the horseradish grater automobile signal we are so familiar with now-a-days, and aroused just the same feeling of resentment which that does. It brought me only a fleeting fame for I soon superseded it *by a magneto-electric call bell* that solved the problem, and was destined to make a long-suffering public turn cranks for the next fifteen years or so, as it never had before, or ever will hereafter.

Perhaps I didn't have any trouble with the plaguey thing! The generator part of it was only an adaption of a magneto shocking machine I found in Davis' Manual of Magnetism and worked well enough, but I was guilty of the jingling part of it. At any rate, I felt guilty when letters began to come from our agents reciting their woes with the thing, which they said had a trick of sticking and failing on the most important occasions to tinkle in response to the frantic crackings of the man who wanted you. But I soon got it so it behaved itself and it has been good ever since, for I have been told that nothing better has ever been invented, that they have been manufactured by the millions all over the world, and that identical jingler to-day does practically all the world's telephone calling.

"Williams' Coffins."—For some reason, my usual good luck I presume, the magneto call bells didn't get my name attached to them. I never regretted this, for the agents, who bought them from Williams, impressed by the long and narrow box in which the mechanism was placed, promptly christened them "Williams' Coffins." I always thought that a narrow escape for me!

The first few hundreds of these call bells were a continuous shock to me for other reasons than their failure to respond. I used on them a switch, that had to be thrown one way by hand, when the telephone was being used, and then thrown back by hand to put the bell in circuit again. But the average man or woman wouldn't do this more than half the time, and I was obliged to try a series of devices, which culminated in that remarkable achievement of the human brain—the automatic switch hook—that only demanded of the public that it should hang up the telephone after it got through talking. This the public learned to do quite well after a few years of practice.

THE BLAKE TRANSMITTER.

You wouldn't believe me if I should tell you a tithe of the difficulties we got into by flexible cords breaking inside the covering, when we first began to use hand telephones!

Then they began to clamour for switchboards for the first centrals, and individual call bells began to keep me awake at nights. The latter were very important then, for such luxuries as one station lines were scarce. Six to twenty stations on a wire was the rule, and we were trying hard to get a signal that would call one station without disturbing the whole town. All of these and many other things had to be done at once, and, as if this was not enough, it suddenly became necessary for me to devise a battery transmitter. The Western Union people had discovered that the telephone was not such a toy as they had thought, and as our 100,000-dollar offer was no longer open for acceptance, they decided to get a share of the business for themselves, and Edison evolved for them his carbon-button transmitter. This was the hardest blow yet.

We were still using the magneto transmitter, although Bell's patent clearly covered the battery transmitter. Our transmitter was doing much to develop the American voice and lungs, making them powerful but not melodious. This was, by the way, the telephone epoch when they used to say that all the farmers waiting in a country grocery would rush out and hold their horses when they saw any one preparing to use the telephone. Edison's transmitters talked louder than the magnetos we were using and our agents began to clamour for them, and I had to work nights to get up something just as good. Fortunately for my constitution, Frank Blake came along with his transmitter. We bought it and I got a little sleep for a few days. Then our little David of a corporation sued that big Goliath, the Western Union Company, for infringing the Bell patents, and I had to devote my leisure to testifying in that suit, and making reproductions of the earliest apparatus to prove to the court that they would really talk and were not a bluff, as our opponents were asserting.

Then I put in the rest of my leisure making trips among our agents this side of the Mississippi to bring them up to date and see what the enemy were up to. I kept a diary of those trips. It reads rather funnily to-day, but I won't go into that. It would detract from the seriousness of this discourse.

Wire Troubles.—Nor must I forget an occasional diversion in the way of a sleet storm which, combining with our wires then beginning to fill the air with house top lines and pole lines along the sidewalks, would make things extremely interesting for all concerned. I don't remember ever going out to erect new poles and run wires after such a catastrophe. I think I must have done so, but such a triffling matter naturally would have made but little impression upon me.

Is it any wonder that my memory of those two years seems like a combination of the Balkan war, the rush hours on the subway and a panic on the stock market?

TURNING TO OTHER ACTIVITIES.

My connection with the telephone business ceased in 1881. The strenuous years I had passed through had fixed in me a habit of not sleeping at night as much as I should, and a doctor man told me I would better go abroad for a year or two for a change. There was not the least need of this, but as it coincided exactly with my desires, and as the telephone business had become, I thought, merely a matter of routine, with nothing more to do except pay dividends and fight infringers, I resigned my position as General Inspector of the Company, and went over the ocean for the first time.

When I returned to America a year or so later, I found the telephone business had not suffered in the least from my absence, but there were so many better men doing the work that I had been doing, that I didn't care to go into it again.

I was looking for more trouble in life and so I went into shipbuilding, where I found all I needed.

Before Mr. Bell went to England on his bridal trip, we agreed that as soon as the telephone became a matter of routine business he and I would begin experimenting on flying machines, on which subject he was full of ideas at that early time. I never carried out this agreement. Bell did some notable work on airships later, but I turned my attention to battleships.

MY GREATEST PRIDE.

Such is my very inadequate story of the earliest days of the telephone so far as they made part of my life. To-day when I go into a central office or talk over a long distance wire or read the annual report of the American Telephone and Telegraph Company, filled with figures up in the millions and even billions, when I think of the growth of the business, and the marvellous improvements that have been made since the day I left it, thinking there was nothing more to do but routine, I must say that all that early work I have told you about seems to shrink into a very small measure, and, proud as I always shall be, that I had the opportunity of doing some of that earliest work myself, my greatest pride is that I am one of the great army of telephone men, every one of whom has played his part in making the Telephone Service what it is to-day.

I thank you.

LOCAL CENTRE NOTES.

LONDON CENTRE.

The Session was opened on the 9th October by Mr. E. J. Woods, A.M.I.E.E., who read a paper on "The Main Underground System of Great Britain." The paper dealt exhaustively with the development of the system and the procedure at Headquarters, and was illustrated by lantern slides showing the progress that had been made particularly since the War. There was a good attendance and an interesting discussion.

The second meeting of the Session was regarded with keen interest. Mr. H. G. S. Peck, B.Sc., M.I.E.E., gave a paper entitled "The Director Exchange in Practice" before a crowded audience, who fully appreciated the excellent reading of the paper and the lucid description of the lantern slide illustrations.

The second half of this meeting was presided over by the President, Col. Purves, who introduced Dr. Thomas Watson, the assistant to Alexander Graham Bell in the invention and development of the telephone, with his customary felicitousness.

Dr. Watson's address "The Birth of the Telephone," was listened to with intense interest and, as he unfolded the enthralling story of the early history and the struggles to develop the telephone system, one could not help but realise how much was due to the pioneers of those far-off days. The Lecture Theatre of the Institution of Electrical Engineers can seldom have held so large an audience and certainly no lecturer can have had a more interested and enthusiastic one. The evening will be a pleasant memory to all for many long years. (*Dr. Watson's address is given in the preceding pages*).

The discussion on Mr. Peck's paper was resumed on Tuesday, the 4th December, and proved of great interest and value. Many of the speakers came from the Contractors' side and expressed their views on circuit design and relay requirements. Mr. Peck ably replied.

INFORMAL MEETINGS.

The first Informal meeting was held on October 23rd, when Mr. P. J. Ridd, M.I.E.E., gave a lecture on "Transmission Efficiency Tests on Subscribers' Apparatus, London District." The subsequent discussion was opened by Mr. Hudson, of the Research Section, who later demonstrated the apparatus on view.

Many members took part in the discussion and it was only the operation of the time limit that enabled the Chairman to close the meeting at the usual time.

Mr. Ridd replied to many of the points raised and many of the members remained behind to explore the mysteries underlying the testing of subscribers' apparatus.

The second meeting was held on 27th November, when Mr. Cowie, M.I.E.E., gave a talk on "Staff Characteristics, Character judging. Talk on personal characteristics." Owing to Mr. Cowie's recent illness the paper was read by Mr. Geer. As was generally expected the matter was both grave and gay and the illustrations were interesting and apposite.

The subsequent discussion was opened by Capt· Hines. Many other speakers followed and it is very encouraging to see that more of the younger members are taking advantage of these meetings to air their views in public.

Mr. Cowie replied with his usual facility and it is the sincere hope of everyone that he will soon be completely restored to health.

T.H.

SCOTLAND WEST CENTRE.

The opening meeting of the session was held in the Society's Room, Royal Technical College, Glasgow, on 1st October, when Mr. H. J. McNamara delivered a lecture on " Ineffective Time."

At the outset, the lecturer stated that it was not intended in the lecture to cover all the points which might be embraced by the title, but rather to confine his remarks to consideration of ineffective time in regard to fairly small development works affecting, say, a city block of buildings, and so leave time for the meeting to discuss the question in all its aspects.

The lecturer pointed out the growing difficulties in regard to safe accommodation for stores and handcarts required for the work, the gradual adoption for garage purposes of areas formerly available, and the increasing necessity for limiting the extent of interference with road traffic, all of these circumstances having a tendency to increase ineffective time. Half a mile was stated to be not an unusual distance between the scene of operations and the point of storage. Methods of conducting the work with a view to limiting ineffective time were dealt with.

After considerable discussion on the points raised by the lecturer, the meeting was thrown open to general discussion of the subject. The prevailing view appeared to be that improved motor transport would do more than anything else to reduce ineffective time in the outlying areas, while improved facilities for storage and transport would improve matters in the city areas.

The second meeting of the Session was held ine the Societies' Room, Royal Technical College, Glasgow, on 28th November. After the routine business had been transacted the film " Voices across the Sea," illustrating the operation of a wireless call between San Francisco and Plymouth, was exhibited.

Mr. E. J. Woods, A.M.I.E.E., Engineer-in-Chief's Office, then read his paper entitled " The Main Underground Trunk Cable System of Great Britain."

Members of the local centre are reminded of the fixture on 2nd February, at 7.30 p.m. under the auspices of the Scietific Society of the Royal Technical College, when Mr. E. S. Ritter, of the Engineer-in-Chief's Office, will deliver a lecture on " Picture Telegraphy," to which I.P.O.E.E. members are specially invited.

H. C. M.

NORTHERN CENTRE.

The opening meeting of the Session was held on the 17th October, when Mr. J. R. Edwards read a paper on " The Output of the Worker, and Suggestions for Improving." Mr. Edwards mentioned co-ordination, supervision, suitability of men, energy and zeal, methods of regulations, and tools as being the leading factors governing the output of the worker, and after making comments under each of these heads he proceeded to suggest :

That no gang should contain more than five men, including the Foreman.

That Local or Advice Note gangs should be comprised of three or four men, including the Foreman.

That more motor vans could be used with advantage, the vans being made to seat four or five men, and be fitted with drum barrows for running off line wire. The fitting of a light crane and winch for pole erections, and the carrying of a telescopic ladder, were also suggested.

Respecting the hours of duty of workmen, Mr. Edwards suggested that during the summer months the 48 hours should be spread over five days only, the author regarding Saturday morning as being an unprofitable work day, and as regards the winter months, it was suggested that eight hours should be worked on each of the six week days. The giving of a bonus to gangs on completed units of work was also suggested. To avoid the loss of time in locating split couplings under made pavements, it was suggested that where conduits are laid on footpaths the line of trench should be marked on the surface by metal studs. The use of short, tubular, galvanised, iron poles in selected areas was also suggested as a measure of economy, as was also the use of a special insulator which would obviate the necessity for "binding-in." As was expected, the paper provoked a brisk discussion.

At a representative gathering held on the 22nd instant, Mr. H. R. J. Dunthorne of this District, who has been promoted to fill the Executive Engineer's vacancy at Canterbury, was presented with a handsome canteen of cutlery. The Superintending Engineer, Mr. J. R. M. Elliott, in making the presentation, referred to the zeal, energy, and conspicuous ability with which Mr. Dunthorne had discharged his duties, and assured Mr. Dunthorne that he carried with him the good wishes of the staff of the Northern District.

Owing to office changes, Mr. T. E. Preston has had to relinguish the duties of Local Librarian, and at the last general meeting a hearty vote of thanks to Mr. Preston, for the ungrudging services he has rendered, was carried with acclamation. Mr. J. W. Kenyon has consented to act as Librarian, and applications for periodicals, etc., should be made to him.

NORTHERN IRELAND CENTRE.

A very pleasant and interesting Social function took place at the Post Office Ex-Service Men's Association Headquarters, Belfast, on the evening of the 14th September last when a large attendance from the Engineering Department and other branches of the Service met to say farewell to Mr. H. H. Broomhead, Assistant Engineer, Belfast, who retired from the Service on the 20th August last, having reached the age limit.

Major Comport, M.C., M.I.E.E., R.E., Superintending Engineer, presided, and was supported by Mr. G. Laslett, Sectional Engineer. After a few pleasing musical numbers, the Chairman introduced the main item of the evening by a feeling reference to the many excellent qualities possessed by the guest, which sentiments were subscribed to by a large number of the Company representing all branches of the Engineering Department. Major Comport on behalf of the Staff asked Mr. Broomhead to accept a wallet of Treasury Notes as a token of the high esteem and regard in which he was generally held throughout the District, together with their best wishes for his future happiness and prosperity. Mr. Broomhead thanked the Company for their kind expression of good wishes and their handsome present and stated that after having been nearly a quarter of a century in Belfast in close touch with the many activities of the Department he could hardly realise that he had ceased to be an active member, and so keenly did he feel this severance from his old colleagues that he had decided to return to the old country, but he would ever cherish the memory of the many good friends he was leaving in Ireland.

It is with deep regret we announce the death under sudden and tragic circumstances of Mr. R. H. Gilliland, Inspector, a prominent and enthusiastic Member of the Institution.

Mr. Gilliland complained of feeling unwell shortly after commencing duty on the 8th December. He suddenly collapsed and died within a short time.

The sympathy of the Committee and Members of the Institution was conveyed to the widow and relatives, and the funeral, which took place on the 11th December, was attended by representatives of all grades of the Service.

NORTH WESTERN CENTRE.

The opening meeting of the 1928-29 Session was held at Preston on the 16th October, 1928, when a paper entitled " The Main Underground Trunk Cable System of the British Isles " was read by Mr. E. J. Woods, A.M.I.E.E., of the Engineer-in-Chief's Office. The Chairman of the Centre (Mr. J. M. Shackleton, M.I.E.E.) presided.

Mr. Woods opened his paper with a brief summary of the growth of the Main Cable System with reference to the more important cables laid up to December, 1927. He then proceeded to review the development of the present high-grade cable, also touching upon the earlier types of cable. Headquarters procedure in relation to cable schemes was explained and the following items covered: — Development Study, Lay-out of cables, etc., District procedure, Duct and Manhole Construction, Boring Machines, Cable Manufacture and Laying, Specifications, Phantom Circuits, Loading Coils, Carrier Wave Telephony, etc. The paper was illustrated by lantern slides and followed by a discussion.

On the 12th November, 1928, a paper was read by Mr. W. S. Procter, of the District Headquarters Technical Section, entitled " Cordless B. Key-sending Positions in Director and non-Director Areas." The paper opened with a general review of the objects of Cordless B. Key-sending Positions and a comprehensive description of the actual equipment and its operations. Mr. Procter then dealt with the arrangement of the apparatus in the Exchange and explained at length the functions of the component parts. The paper was illustrated by lantern slides and there was a discussion.

The third meeting of the Session was held at Preston on the 10th December, 1928, when Mr. T. E. Tootell read a paper entitled " Some Notes on the Maintenance of Machine Telegraphs." Mr. Tootell reviewed the systems leading up to the machine telegraphs now in use and described in general terms the functions of the various machines. The details of the Wheatstone Perforator, Transmitter and Receiver, the Baudot, Teleprinter 2A and 3A, etc., were explained and the maintenance of the apparatus fully described. The paper was illustrated by lantern slides, and a discussion followed.

D.B.

THE INSTITUTION OF P.O. ELECTRICAL ENGINEERS NOTICES.

BOOTH-BAUDOT AWARD.

The Council wishes to call attention to the " Booth-Baudot Award " of £5 which is now offered annually for the best improvement in Telegraph, Telephone or Wireless Apparatus or Systems. The award for the year 1928 is governed by the following conditions:—

1. The Award will be restricted to employees of the British Post Office.
2. Applications for the Award should be made between 1st January and 31st March, 1929, and such applications should refer to improvements made, or suggested, during the twelve months ending 31st December, 1928.

   Attention is drawn to the fact that recipients of Awards *via* the Post Office Awards Scheme in respect to any improvement in telegraph, telephone or wireless apparatus or systems are eligible to apply for the Booth-Baudot Award in respect thereto.
3. The Award may be withheld at the discretion of the Council of the Institution of Post Office Electrical Engineers if, after full consideration of the applications received, the adjudicators appointed by the Council are of the opinion that no award is warranted.
4. Applications for the Award, accompanied by full details of the improvement, should be addressed to the Secretary, The Institution of Post Office Electrical Engineers, G.P.O. (Alder House), London, E.C.1.

R. V. Hansford,
Secretary,

December, 1928.

LOCAL CENTRE PROGRAMMES.

SCOTLAND WEST CENTRE.

1928.	
1 Oct. or 5 Nov.	H. J. McNamara. " Underground Construction."
28 Nov.	E. J. Woods, A.M.I.E.E. (*E.-in-C.O.*). " The Main Underground Trunk Cable System of the British Isles."
1929.	
4 Feb.	A. Thomson. " Strowger Automatics." (Supplementary to last year's paper).
4 Mar.	A. Arnold. " Glasgow Repeater Station."
2 Apl.	A. Hudson. (*E.-in-C.O.*). " Routine Testing of Subscribers' Transmitters and Receivers for Efficiency in Situ."

SCOTLAND EAST CENTRE.

1928.	
27 Nov.	E. J. Woods, A.M.I.E.E. (*E.-in-C.O.*). " The Main Underground Trunk Cable System of the British Isles."
18 Dec.	R. Goodfellow. " Training of Youths."
1929.	
15 Jan.	G. H. Douglas. " Notes on Battery Course, May, 1928."
19 Feb.	H. Burgher. " Cabling and Jointing."
19 Mar.	Short papers and informal discussions.
16 Apl.	*To be arranged.*

NORTH IRELAND CENTRE.

1928.
6 Nov. Chairman's Address.
4 Dec. (*a*) Film—"Voices across the Sea."
(*b*) W. S. Keown.
"Beams, Girders and Reinforcements as used in Underground Construction."

1929.
15 Jan. *To be arranged.*
12 Feb. R. T. Robinson. (*E.-in-C.O.*).
"Motor Transport."
12 Mar. E. J. Woods, A.M.I.E.E. (*E.-in-C.O.*).
"The Main Underground Trunk Cable System of the British Isles."
16 Apl. A. S. Renshaw. (*E.-in-C.O.*).
"Some considerations relating to the Clerical Organisation of the Engineering Department."

THE INSTITUTION OF P.O. ELECTRICAL ENGINEERS.

Officers of Colonial and Foreign Telegraph Administrations who are engaged in Electrical Engineering Works may be admitted as Colonial and Foreign Corresponding Members respectively, after application.

Subscription payable annually in advance on 1st April in each year :

Colonial Members	... ...	£1 0 0
Foreign ,,	... ...	£1 10 0

These sums include Annual Subscription to the Journal of P.O. Electrical Engineers and the supply of all Professional Papers issued during the period covered by subscription.

Forms of application for Colonial and Foreign Membership can be obtained on application to

The Secretary,
Institution of P.O.E. Engineers,
G.P.O., Alder House, E.C.1

or the undermentioned gentlemen who have kindly agreed to act as representatives of the Institution in their respective countries :—

R. Badenach, Esq., B.Sc. (Melb.),
Chief Electrical Engineers Office,
Postmaster Generals Department,
Treasury Gardens,
Melbourne,
Australia.

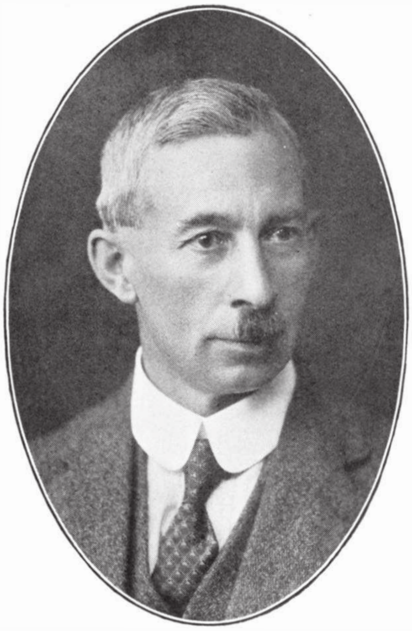
H. C. Brent, Esq.,
The Laboratory,
G.P.O.,
Wellington, N Z.

N. N. Banerjee, Esq., A.M.I.E.E. (Ind.),
Divisional Engineer, Telegraphs,
Calcutta West Division,
8, Wellesley Place,
Calcutta,
India.

A. T. Kingston, Esq., M.B.E., A.M.I.E.E.,
Office of the Chief Engineer,
Telegraphs & Telephones,
C.T.O.,
Colombo,
Ceylon.

A. J. Kellaway, Esq.,
Department of Posts and Telegraphs,
P.O. Box 366,
Pietermaritzburg,
South Africa.

MR. J. W. ATKINSON, M.I.E.E.



Mr. J. W. Atkinson.

Mr. J. W. Atkinson, who, on 1st June last, was promoted to the Superintending Engineership of the North-Eastern District, with headquarters at Leeds, entered the service of the Post Office as a Telegraph Learner in April, 1893. After six years' work as a telegraphist he was transferred to the Engineering Department as a Junior Clerk; and, in July, 1900, was promoted to a Clerkship in the Engineer-in-Chief's Office, where he served under Mr. R. McIlroy, (now) I.S.O., who at that time was personal assistant to the Engineer-in-Chief, Mr. J. Hookey.

In 1902, Mr. Atkinson competed for a Second Class Engineership at Headquarters and was assigned to the Examination Section, under the late Mr. H. Hartnell, M.I.E.E., ; a few months later he was selected to act as personal assistant to the late Mr. Martin F. Roberts, M.Inst.C.E., Assistant Engineer-in-Chief, thus coming into close contact with the numerous engineering and administrative problems associated with the pre-1911 London Telephone System.

In September, 1907, Mr. Atkinson took charge of the Sutton and Epsom Section, transferring to Kingston in March, 1908; and in October, 1910, he was promoted to a First Class Engineership in charge of the Bristol Section. A year later he was assigned to one of the "Groups" formed for the purpose of checking the National Telephone Company's plant inventory and for collecting data for use in the valuation proceedings.

In 1911, Mr. Atkinson was nominated by the Engineer-in-Chief (Major W. A. J. O'Meara, C.M.G.) for an Assistant Staff Engineership and, after examination by the Civil Service Commissioners, was appointed on 9th December, 1911, to the Construction Section, the Staff Engineer being Mr. J. Sinnott, (now) O.B.E.

In March, 1926, having expressed a desire to refresh his knowledge of District activities, Mr. Atkinson was transferred to the London Engineering District and (in his own words) thus had the pleasure of renewed association with Mr. McIlroy.

It is Mr. Atkinson's ideal that the British P.O. Communication Services shall be equal, at least, to those of any other administration in the world; and it may be assumed that this explains his marked interest in the work of the Institution of Post Office Electrical Engineers. He was one of the founders of the Society of Post Office Engineers, whose intended work in the sphere of technical education was taken over by the Institution; he acted as Secretary to the Institution "Formation Committee" and for the first two years to the Institution itself; and since then has served as Honorary Treasurer to the Institution, and as a Member and also as Chairman of the Board of Editors of this Journal.

MR. H. WILSON.

MR. H. WILSON.

MR. WILSON retired from the Service on the 31st July, but returned to Cardiff in the first week in October, where he was entertained by the South Wales District and presented with a half-hunter gold watch and a grandfather's clock fitted with Westminster chimes, and also with an inkstand from the office Cricket Club. Taking the keenest interest in the welfare of the staff—it is said he was known personally by and knew the idiosyncracies of every member of the South Wales district—he was immensely popular and consequently secured the enthusiasm and best efforts of all grades of the service, and his retirement after one year's extension was deeply regretted throughout the district.

He entered the service as a telegraphist at Newcastle-on-tyne on the 17th July, 1882, and immediately began to take an interest in the technical side of the work. He found time, however, to join the volunteers and for ten years he was an active member of the Tynside Division of Submarine Miners. Later in life this training bore fruit and he rendered valuable service in the volunteer signal corps raised in London during the war and known colloquially as "Gunton's Gurkhas." Mr. Wilson, in 1892, was appointed a Relay Clerk at Morfa Nevin, and four years later he was promoted to Second Class Engineer in charge of Carmarthen Section. When the P.O. started the telephoning of London, selected engineers were chosen from the districts for the work, and Mr. Wilson came to Hampstead as First Class Engineer in June, 1902. He was nominated to sit at a competitive Civil Service examination, and in 1908 he was appointed Staff Engineer Second Class in the Designs Section. During his service at headquarters he acted as guide, philosopher and friend to various batches of young engineers recruited from outside the service and initiated them into the mysteries of telephone and telegraph practice. He was also a member of the Awards Committee, P.O. representative on the B.E.S.A. Committee which drew up the specification for materials used in and the construction of Chemical Fire Extinguishers, and for twenty years he was lecturer in Telegraphy and Telephony at Battersea Polytechnic. Second in command to the present Engineer-in-Chief in the Designs Section, Mr. Wilson rendered very valuable service during the war period and assisted Col. Purves in the design and supply of new signal apparatus for the armies in the field. He has many humorous incidents to tell of his experiences with inventors, whose ideas were not always so indispensable to the Department as their authors imagined.

In April, 1924, Mr. Wilson went to South Wales as Assistant Superintending Engineer and three months later he took charge of the district as Superintending Engineer.

In spite of his forty-six years strenuous service, Mr. Wilson does not think he requires a rest. He has joined the firm of Thomas Watson and Son, Dudden Hill Lane, scientific instrument makers, as consultant and technical representative, and is carrying on with his unfailing energy and good humour.

W. S. TINSLEY, M.I.E.E.

Mr. W. S. Tinsley.

Mr. W. S. Tinsley, Sectional Engineer at Bradford, retired at the end of October after completing forty-three years' service. Mr. Tinsley commenced his service in the Telegraph Department at Hull in 1885, and in 1894 he was nominated to a Junior Clerkship in the Engineering Department at Liverpool. This was followed by promotion to Newcastle in 1896. Five years later he was promoted to Engineer in London, and in 1909 a further step was taken when he took charge of the Bradford Section.

Mr. Tinsley was in charge of the Bradford Section for nineteen years. It is well known that this section is a heavy one. To estimate Mr. Tinsley's services to the Department one must visualise the conditions existing in the West Riding some years ago, when Bradford was served mainly with overhead wires, when the Exchanges were worked by systems since displaced, and overloaded routes of open wires crossed the moorland in all directions. All these things are better tō-day, and the knowledge that he has helped, materially, towards this improvement is Mr. Tinsley's most satisfactory reward.

As a mark of esteem from colleagues and friends, Mr. Tinsley was presented with a silver tea service and a gramophone, at a complimentary dinner in Bradford. The chair was taken by Mr. J. C. Walker, Assistant Engineer. Those present included the Superintending Engineer, Mr. J. W. Atkinson; the late Superintending Engineer, Mr. T. B. Johnson; Mr. W. J. Bailey, Staff Engineer, London; Mr. G. S. Wallace, Assistant Superintending Engineer; Mr. G. Richardson, Sectional Engineer, Birmingham; Mr. Bell Smith, Postmaster of Bradford; Mr. T. A. Bates, District Manager, and Mr. H. B. Sutcliffe, late District Manager.

It is the wish of his many friends that Mr. Tinsley will be happy in the years to come. Judging by his variety of interests, such as golf, bowls and music, there should be little doubt in the matter. As Honorary Secretary of the Bradford Musical Union he has a wide circle of friends. Mr. Tinsley will not be leaving Bradford, and there will be much opportunity of meeting him in the future. This will be a particular pleasure to his old friends in the N.E. District.

G.M.B.

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

Promotions.

Name.	Grade.	Promoted to	Date.
Pink, E. A.	Executive Engineer, Bristol Section, S. West District.	Assistant Staff Engineer, Construction Section, E.-in-C.O.	23-9-28
Upton, S.	Executive Engineer, Preston Section, N. West District.	Assistant Superintending Engineer, N. West District.	15-8-28
Cornfoot, T.	Executive Engineer, Liverpool External Section. S. Lancs. District.	Assistant Superintending Engineer, S. East District.	3-1-29
Wise, Capt. F. H.	Executive Engineer, Exeter Section, S. West District.	Assistant Superintending Engineer, S. East District.	1-3-29
Wildgoose, G. H. A.	Assistant Engineer, Technicla Section, S. Lancs. District.	Executive Engineer, Technical Sect. S. Lancs. District.	21-11-28
Buchanan, J.	Assistant Engineer, Preston Section, N. West District.	Executive Engineer, Preston Sect., N. West District.	21-11-28
Coxon, J.	Assistant Engineer, Power Section, N. Wales District.	Executive Engineer, Technical Sect N. Wales District.	29-11-28
Clack, C. W.	Assistant Engineer, Designs Section, E.-in-C.O.	Executive Engineer, Designs Sect., E.-in-C.O.	1-12-28
Akast, A. C. S.	Chief Inspector, London Engineering District.	Assistant Engineer, London Engineering District.	21-11-28
Nichols, J. C.	Chief Inspector, S. Midland District.	Assistant Engineer. N. Mid. District.	To be fixed later.
Chapman, F. G.	Chief Inspector, Stonehaven Radio.	Assistant Engineer, Leafield Radio.	To be fixed later.
Stevens, F.	Chief Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	21-11-28
Soper, R. E.	Chief Inspector, S. West District.	Assistant Engineer, E.-in-C.O.	To be fixed later.
Carr, A. S.	Chief Inspector, N. West District.	Assistant Engineer, N. West District.	21-11-28
Corkett, H.	Chief Inspector, London Engineering District.	Assistant Engineer, London Engineering District.	21-11-28
Woodhouse, B. W.	Chief Inspector, London Engineering District.	Assistant Engineer, E.-in-C.O.	To be fixed later.
Cohen, A. J.	Chief Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	21-11-28
Mabey, H.	Chief Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	To be fixed later.
Hewett, J. E.	Inspector, S. Wales District.	Chief Inspector, S. Wales District.	To be fixed later.
Wood, W. T.	Inspector, S. Lancs. District.	Chief Inspector, S. East District.	To be fixed later.
Bines, H. T.	Inspector, London Engineering District.	Chief Inspector, London Engineering District.	To be fixed later.
Beal, F. F.	Inspector, London Engineering District.	Chief Inspector, London Engineering District.	To be fixed later.
Storey, W. J.	Inspector, S. Lancs. District.	Chief Inspector, S. East District.	To be fixed later.
Hopper, E.	Inspector, N. West District.	Chief Inspector, N. West District.	1-12-28
Taylor, S. A.	Inspector, N. West District.	Chief Inspector, London Engineering District.	To be fixed later.
Lisle, R.	Inspector, N. Wales District.	Chief Inspector, S. Midland District.	To be fixed later.
Mitchell, C. A.	Inspector, Eastern District.	Chief Inspector, Eastern District.	To be fixed later.
Pendry, S. D.	Inspector, S. Midland District.	Chief Inspector, S. Midland District.	To be fixed later.
Beazer, F. C.	Inspector, London Engineering District.	Chief Inspector, London Engineering District.	To be fixed later.
Hourigan, H. F.	Unestablished Skilled Workman Testing Branch.	Inspector, Testing Branch.	14-11-28

STAFF CHANGES.

RETIREMENTS.

Name.	Grade.	Districts.	Date.
France, W. M.	Staff Engineer.	E.-in-C.O.	31-10-28
Francis, F. W.	Assistant Staff Engineer.	E.-in-C.O.	30-11-28
Tinsley, W. S.	Executive Engineer.	N. Eastern.	31-10-28
Greening, A. C.	Assistant Engineer.	London.	31-10-28
Wenman, H. E. A.	,, ,,	London.	30-11-28
Jones, H.	Inspector,	S. Wales.	5-9-28
Reed, W.	,,	Northern.	28-9-28
Sly, W. B.	,,	S. Midland.	13-10-28
Williams, W. R.	,,	S. Lancs.	18-10-28
Roberson, H. T.	,,	London.	20-10-28
Holliday, R. W.	,,	London.	31-10-28

DEATHS.

Name.	Grade.	District.	Date.
Hartnell, G. T.	Chief Inspector.	E.-in-C.O.	10-11-28
Robinson, H. E.	Inspector.	S. West.	8-9-28

TRANSFERS

Name.	Rank.	From.	To	Date.
Fletcher, Capt. J. E.	Executive Engineer.	S. Lancs. Dist.	N. East Dist.	1-11-28
Jackson, D.	Assistant Engineer.	Testing Branch	E.-in-C.O.	1-12-28
Jackson, J. M.	,, ,,	N. West Dist.	S. Lancs. Dist.	1-11-28
Horn, C. O.	,, ,,	Rugby Radio.	E.-in-C.O.	7-11-28
Manning, G.	,, ,,	E.-in-C.O.	L.E.D.	25-11-28
Pritchard, E. J.	Inspector.	N. Wales.	E.-in-C.O.	28-10-28
Gill, F. W.	,,	S. West.	,,	25-11-28
Hawkins, N. A.	,,	S. East.	,,	25-11-28
Campbell, P. J.	,,	S. Mid.	,,	1-11-28
Collman, E. L.	,,	N.	E.-in-C.O.	11-11-28

APPOINTMENTS.

Name.	From.	To	Date.	
Vickers, G. H.	Assistant Officer-in-Charge Cairo Radio.	Assistant Engineer, Rugby Radio.	23-11-28	
Knowers, A. D. V.	Inspector E.-in-C.O.	Probationary Assistant Engineer, E.-in-C.O.	To be fixed later.	*Limited Competition.*
Berkeley, G. S.	,, ,,	Probationary Assistant Engineer, E.-in-C.O.	14-11-28	
Turner, H. M.	Inspector, S. Lancs.	Probationary Assistant Engineer, S. Lancs.	26-11-28	
Chew, W. G. N.	Inspector, E.-in-C.O.	Probationary Assistant Engineer, E.-in-C.O.	14-11-28	
Jones, C. E. P.	,, ,,	Probationary Assistant Engineer, E.-in-C.O.	13-11-28	
Morrell, F. O.	,, ,,	Probationary Assistant Engineer, London.	24-11-28	*Open Competition.*
Howard, J. L.		Probationary Assistant Engineer, E.-in-C.O.	3-12-28	
Jarvis, R. F. J.		Probationary Assistant Engineer, E.-in-C.O.	To be fixed later.	
Franklin, R. H.		Probationary Assistant Engineer, London.	23-11-28	

CLERICAL ESTABLISHMENT.

PROMOTIONS.

Name.	From	To	Date.
Smalley, A. T.	Acting Executive Officer. E.-in-C.O.	Executive Officer, E.-in-C.O.	29-9-28
Gordon, F.	Clerical Officer, E.-in-C.O.	Acting Executive Officer, E.-in-C.O.	29-9-28
Crawford, G. W. J.	Higher Clerical Officer, Scotland West District.	Staff Officer, Scot. West District.	1-11-28
Bailey, W. R.	Clerical Officer, Scotland West District.	Higher Clerical Officer, Scot. West District.	1-11-28
Airey, J.	Clerical Officer, N. West District.	Higher Clerical Officer, Scot. East District.	11-11-28

RETIREMENTS.

Name.	Rank.	District.	Date.
Crotch, A.	Staff Officer.	E.-in-C.O.	31-12-28
Elener, G. A.	,, ,,	Scot. West District.	31-10-28
Pym, W. H.	Higher Clerical Officer,	Scot. East District.	25-10-28
Riley, R.	,, ,,	S. Midland.	4-12-28

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